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State of South African Manufacturing, its potential and resources required for further development of PV Value Chains

Final Report

SolarPower Europe

SAPVIA
South African Photovoltaic Industry Association

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Contact: Secretariat of the South African – German Energy Partnership
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
333 Grosvenor Street | Hatfield Gardens Office Park | Pretoria
P.O. Box 28102, Sunnyside, 0002
South Africa
Head of Secretariat: Henrik Hartmann
Email: henrik.hartmann@giz.de
Website: www.energypartnership.org.za
Tel.: +27 12 423 5900

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Acronyms

Acronym	Expanded term
ACfTA	African Continental Free Trade Agreement
AFSIA	African Solar Industry Association
APAC	Asia Pacific
B-BBEE	Broad-Based Black Economic Empowerment
BI	Black Industrialist
BoP	Balance of Plant
BW	Bid Window
C & I	Commercial and Industrial
C, I & M	Commercial, Industrial and Mining
CBAM	Carbon Border Adjustment Mechanism
CdTe	thin-film cadmium telluride
CSDDDSS	Corporate Sustainability Due Diligence Directive and Solar Stewardship
CSIR	Centre for Scientific and Industrial Research
CSP	Concentrating Solar-thermal Power
DBSA	Development Bank of Southern Africa
DFI	Development Finance Institution
DMRE	Department of Mineral Resources and Energy
DWYPWD	Department of Women, Youth and Persons with Disabilities
EA	European cooperation for Accreditation
EoL	End of Life
EPP	Extended Producer Responsibility
ESPIA	European Solar Photovoltaic Industry Alliance
EU	European Union
EWSETA	Energy and Water Sector Education and Training Authority
FIT	Feed in Tariff
FTE	Full Time Equivalent
GESI	Gender Equality and Social Inclusion
GW	Gigawatt
IAPPS	International Agency for Photovoltaic Power Systems
IDC	Industrial Development Corporation
IEA	International Energy Agency
IEC	International Electrotechnical Commission
ILAC	International Laboratory Accreditation Cooperation
IOS	International Organization for Standardization
IRA	Inflation Reduction Act (US)
IRENA	International Renewable Energy Association
IRP	Integrated Resource Plan
JET-IP	Just Energy Transition Investment Plan
JT	Just Transition
JTF	Just Transition Fund
MW	Megawatt
NEF	National Empowerment Fund
NERSA	National Energy Regulator of South Africa
NMISA	National Metrology Institute of South Africa
NRCS	National Regulator for Compulsory Specifications
NRCS	National Regulator for Compulsory Specifications

Acronym	**Expanded term**
OEMs	Original Equipment Manufacturers
PPA	Power Purchase Agreement
PPPF	Preferential Procurement Policy Framework
PPPFA	Preferential Procurement Policy Framework Act
PYEI	Presidential Youth Employment Intervention
RE	Renewable Energy
REI4P	Renewable Energy Independent Power Producer Procurement Programme
SABS	South African National Bureau of Standards
SADC	Southern African Development Community
SAIEE	South African Institute of Electrical Engineers
SANAS	South African National Accreditation System
SANS	South African National Standards
SAPVIA	South African Photovoltaic Industry Association
SAREM	South African Renewable Energy Masterplan
SAWEA	South African Wind Energy Association
SDG	Sustainable Development Goals
SEDA	Small Enterprise Development Agency
SEZ	Special Economic Zone
SME	Small and Medium Enterprise
Solar PV	Solar Photovoltaic
SSEG	Small Scale Embedded Generation
TVET	Tertiary Vocational Education and Training

Introduction

Dear Reader,

As the country grapples to meet electricity demand due to crippling episodes of loadshedding, the renewable energy industry in general, and the solar PV industry specifically, has played a pivotal role in lessening the negative impact on households and businesses. Exponential growth in the uptake of solar PV has seen South Africa import billions worth of solar PV components over the last few years.

The South African Photovoltaic Industry Association (SAPVIA) believes that there is value in localising the manufacturing of some components to bolster national industrialisation imperatives, create much-needed jobs and possibly export to other jurisdictions including Europe. It is for this reason that we embarked on the study with our European counterparts to further unpack opportunities following our initial study concluded in 2022.

This study is informed by our strategic objectives namely: to shape and influence regulations and policy, to educate stakeholders and SAPVIA members and to foster collaborations and partnerships that increase the rate of solar PV deployment. We are immensely proud to publish this research report as it not only aligns with our organisation's strategic objectives but seeks to unlock industrialisation opportunities in South Africa.

This report, building on a report released by SAPVIA in 2022 titled **the localisation potential of the South African solar photovoltaic (PV) industry and recommendations to support local manufacturing in South Africa**, focuses on an updated analysis of South Africa's solar PV manufacturing value chain, aiming to inform public policies and private investments for strengthening local manufacturing and assembly. This research further aligns with the European Union's renewable energy goals, to diversify and integrate the global solar supply chain while strengthening private sector collaboration between the EU and South Africa to bolster solar PV industrial development.

Further, the research seeks to inform policy makers of the global interconnected structure of the solar PV value chain, showcasing the nature and extent of industrial policy support for component manufacturing in various global markets. These policy interventions have driven the rapid rise and subsequent concentration of solar PV component manufacturing in China. This development underscores the need for strategic policies and investments to capitalize on manufacturing opportunities in the solar PV market in South Africa and to leverage global shifts in renewable energy demand and supply.

In conjunction, understanding the local dynamics within the South African PV sector is essential for gauging the potential for localization. Issues such as regulatory hurdles, supply chain constraints, and skills shortages must be collectively addressed through appropriate and workable policy support mechanisms and interventions to unlock the identified opportunities.

Leveraging this study, SAPVIA and the project partners recommend practical and sustainable policy approaches for South African policy makers. This requires collaboration with the private renewable energy sector to promote achievable solar PV industry localization.

SAPVIA wishes to thank the project partners, Solar Power Europe for sharing in the vision for a diversified global solar PV value chain. We would also like to appreciate the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) through the South African - German Energy Partnership for their financial and non-financial support throughout the development and dissemination of the study. To our members, partners and stakeholders who contributed to this study, a massive thank you. We hope the study will shape policy and inform the implementation of empirically informed localisation of the solar PV value chain. Here is to the sustainable and thriving solar PV industry in South Arica.

Thank you for reading.

Dr Rethabile Melamu
CEO, SAPVIA

Executive summary

This study provides an updated analysis of the South African solar PV manufacturing value chain. It builds on prior research to inform public policy options and private investment decisions for deepening component manufacturing and assembly, installation, maintenance, and end of life services in South Africa and for export. This includes building capabilities to supply the South African, and the broader African and European markets in partnership with European PV players, contributing to decarbonisation, job creation and economic inclusion, as well as supporting the European Union (EU) to meet its renewable energy goals. This research is driven by the intention of the South African Photovoltaic Industry Association (SAPVIA) and SolarPower Europe to strengthen private sector cooperation between the EU and South Africa to support global solar supply chain diversification and integration.

The objective of the study is to provide an updated analysis of South African solar PV manufacturing, its potential and resources required for further development. It aims to assist policy makers, investors, and civil society to inform mechanisms to develop a strong domestic PV value chain in South Africa that will create jobs by identifying economic opportunities along the chain to address the triple challenge in South Africa of poverty, inequality and unemployment and make a significant contribution to the country's decarbonisation agenda. It further aims to inform measures to support greater integration of the South African and EU solar PV value chains, reinforcing the respective solar PV industries in both markets and creating valuable partnerships to combat climate change.

There has been a dramatic increase in the installation of solar PV worldwide since 2010 led by China. Solar PV has become the largest source of renewable energy (RE) and is set to overtake both coal and natural gas to become the largest source of energy overall by 2027, providing over one fifth of global power capacity. The growth of solar PV manufacturing has been overwhelmingly driven by government subsidies and other forms of public support. All countries that have either established a significant presence in solar PV manufacturing or have ambitions to do so have put in place various support measures. Five jurisdictions are considered in this report: China, the US, the EU (particularly Germany), India and Türkiye. All these jurisdictions have put in place a range of demand and supply side measures. On the demand side these include local-content requirements linked to measures to stimulate domestic solar PV demand such as feed-in-tariffs and auctions. On the supply side they include support for Research and Development (R&D), tax credits and allowances, grants, and low-cost financing.

China has established itself as both the world's largest installer and manufacturer of solar PV, accounting for over 80 percent world market share in all stages of panel production. Chinese dominance in solar PV has been achieved through a combination of massive state subsidisation to drive economies of scale for the export market in its initial stages, bolstered by the world's large solar PV deployment programme. This has driven an exponential reduction in the price of solar PV panels and modules with periods of global overcapacity. Prices of solar panels fell from around US$5.00 per watt in 2005 to US$0.38 in 2019. In the US today, polycrystalline panels have an average cost of US$0.90 to US$1 per watt.[1]

[1] Brill, R., Ogletree, A., & Resnick, D. (2023). How Much Do Solar Panels Cost In 2023? Solar Panel Costs 2023: By Type, Installation And More – Forbes Home

A confluence of geopolitical and economic factors has prompted the US and EU to introduce industrial, trade and regulatory policies that seek to limit their overwhelming reliance on China for supply of key renewable and digital sub-systems and products, including solar PV. These include the US's Inflation Reduction Act and the EU's REPowerEU Plan and related strategies including the Green Deal Industrial Plan and EU Solar Strategy. The EU's policy intent to limit reliance on supply of key solar PV subsystems and products on any single country to no more than 60 percent presents an opportunity for developing countries such as South Africa.

Some developing countries have sought to create additional industrial capabilities in solar PV. Türkiye has introduced a 10-year feed-in tariff (FIT) for solar PV systems installed between July 1, 2021, and Dec. 31, 2030, and an extra 5-year tariff for solar projects that use PV components produced in Türkiye. The Turkish authorities hope to allocate around 20 GW of new PV capacity by 2030 through this scheme.[2] India installed 6,794 MW of solar PV in H1 (January – June) 2023, Solar now accounts for 54 percent of India's total 129.6 GW renewable energy capacity, a 3 percent expansion from 51 percent over the last year.

India and Türkiye have implemented policies to create some integrated solar PV panel and module production while South Africa and other developing countries have policies to promote assembly of solar PV modules based on imports of panels, overwhelmingly from China. An important consideration will be how Chinese companies adapt to an environment in which it becomes more difficult to directly access the United States (US) and European Union (EU) markets. One nascent response is for Chinese manufacturers to invest in plants in third countries with good market access to the US or EU markets or both.

The solar PV panel and module value chain have captured the primary attention of policy makers, including in South Africa. However, localization opportunities are present in South Africa for major solar PV sub-systems as well: including mounting and tracking structures; inverters; and manufactured inputs into electrical and civil balance of plant (BoP).

The development of the solar PV, and broader RE market has until recently been dominated by public utility scale procurement through the Renewable Energy Independent Power Producer Procurement Programme (REI4P). Localization requirements linked to the REI4P have provided some support for parts of a domestic value chain to emerge across the various solar PV sub-systems. A broad ambition to promote domestic manufacturing has, however, been undermined by periods of policy uncertainty, and flaws in policy and implementation. Consequently, several factories that were established to serve REI4P demand closed or have been operating below full capacity, including projects supported by incentives and financing from the Industrial Development Corporation (IDC) of South Africa.

Since the baseline report of 2022[3] there have been some significant changes in current and anticipated sources of demand and some more limited changes to the structure of the industry.

In the first instance, various policy reforms since 2019 have shifted the source of demand for solar PV from an overwhelming reliance on the public utility scale market to private large scale, Commercial, and Industrial (C&I) and residential small scale embedded generation (SSEG) projects.

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[2] PV magazine (2023). Turkey introduces 10-year FIT for solar, other renewables.[Turkey introduces 10-year FIT for solar, other renewables – pv magazine International (pv-magazine.com)]

[3]United States Agency for International Development, *South African Solar PV Value Chain: Analysis and Strategies for Increasing Localization* (2022), https://pdf.usaid.gov/pdf_docs/PA00ZHT4.pdf.

While solar PV is likely to remain an important part of the Integrated Resource Plan (IRP) and hence REI4P procurement going forward, private projects will be of a similar magnitude.

In the second instance, South Africa has developed significant, albeit uneven, capabilities across some solar PV sub-systems. This includes assembly of modules; mounting and tracker systems; battery storage (some linked to solar PV); inverters and inputs into electrical BoP, particularly AC cables. However, the overall solar PV value chain remains fragmented and underdeveloped, albeit with significant opportunities for growth.

The employment footprint, and associated poverty reduction, of solar PV is significant but varies along the value chain. A 2022 report commissioned by SAPVIA[4] estimated that 20,000 (full-time-equivalent) people were employed in construction and installation, 3,000 in project development and 3,000 in manufacturing. Direct manufacturing employment intensity varies significantly with module assembly relatively capital intensive and mounting structures and trackers, and electrical balance of plant more labour intensive. However, based on World Bank estimates each direct manufacturing job generates 3.8 additional jobs elsewhere in the economy, bringing the total approximate manufacturing employment impact to around 14,400 jobs (3,000 direct and 11,400 indirect). The explosion of commercial, industrial, and residential SSEG rooftop solar installations since early 2022 has undoubtedly boosted employment linked to installation, but no specific estimates are yet available. Similarly, the potential employment impact of a nascent end-of-life and recycling industry remains to be quantified.

Some relevant conclusions can be drawn from the evolution of the South African solar PV value chain since 2011. Initially, while not insignificant, the South African market is not big enough to support substantial growth in solar PV related investment and international competitiveness should be developed both to compete more effectively in the domestic market and take advantage of export market opportunities. Competitive participation in the solar PV value chain and its sub-systems requires investment at scale. In the solar panel sub-systems, competitive investments need to be of a 'giga-factory' scale (although no announcements of investments outside China at this scale were made in 2022) and require continuous reinvestment to adapt to ongoing improvements in panel technologies. Subsidies, other forms of cheap capital, strategic use of public procurement, trade and regulatory measures are pervasive. There are no countries operating in the solar PV space that do not have substantive incentives and other support measures to promote industry development. The changing global and domestic environment opens potential opportunities for the deepening of South African manufacturing in solar PV value chains. The extent to which these opportunities are seized depend on both the actions of the South African government and on EU partners. It therefore proposes recommendations both for South African public policy recommendations and for European partners.

[4] SAPVIA (2022) South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa* (2022).

1. Strategic context

1.1. Purpose and objectives

This study builds on prior research that has established a baseline understanding of the state of manufacturing and localisation in the South African solar PV value chain, notably *the 2022 South African solar PV Value Chain Analysis and Strategies for Increasing Localization* study[5]. It updates research on the state of the South African solar PV value chain to make concrete proposals for deepening component manufacturing and assembly, installation, maintenance, and end of life services in South Africa and for export. This includes building capabilities to supply the South African, and the broader African and European markets in partnership with European PV players, contributing to decarbonisation, job creation and economic inclusion, as well as supporting the EU to meet its renewable energy goals. This research is driven by the intention of SAPVIA and SolarPower Europe to strengthen private sector cooperation between Europe and South Africa to support global solar supply chain diversification and integration.

The core objective of the study is to provide an updated analysis of the state of the South African solar PV manufacturing, its potential and resources required for further development of PV value chains. Specifically, it aims to:

- Build on previous solar PV value chain localisation studies.
- The study has the dual objective of informing mechanisms to:
    - Develop a strong domestic solar PV value chain in South Africa that will create jobs by identifying economic opportunities along the chain to address the triple challenge of poverty, inequality and unemployment and make a significant contribution to the country's decarbonisation agenda; and
    - Integrate South African and EU solar PV value chains, reinforcing the respective solar PV industries in both markets and creating valuable partnerships to combat climate change and diversify the global solar PV value chain within the scope of this assignment.

Ultimately, the study aims to support the development of a strong South African solar PV value chain and the integration of South African and EU solar PV value chains through the creation and support of valuable partnerships and investments resulting in improved abilities to combat climate change and reduce dependency on fossil fuels. At the same time, in so doing, an important contribution can be made to addressing the triple challenge.

[5] United States Agency for International Development, *South African Solar PV Value Chain: Analysis and Strategies for Increasing Localization*.

1.2. International context

1.2.1.Strategic international context

South Africa's energy transition is affected by the increasing impact of climate change, geo-political shifts, and supply chain reconfiguration.

Africa, including Southern and South Africa, is predicted to be the most negatively affected by climate change through rising temperatures, increasing frequency and severity of adverse weather events and climate induced biodiversity loss.

Geo-political and technological shifts are having an important impact on the reconfiguration of the global solar PV supply chain. In addition to climate risks, South Africa faces economic risks from the recent introduction by the EU of the Carbon Border Adjustment Mechanism (CBAM) and the likelihood of the US following suit.[6] In the light of Russia's invasion of Ukraine, the EU has sought greater energy sovereignty through a faster transition to RE and energy system decarbonisation.

While Germany pioneered mass production of solar PV modules in the 1990s, China has come to dominate global solar PV manufacturing through enormous scaling of investment in the sector. The exponential growth in the scale of solar PV has in turn driven an 88 percent reduction in in prices between 2010 and 2021.[7] Both the US and the EU aim to lessen their reliance on Chinese supply of products and components required for the green energy and digital transition.

Accordingly, the EU has recently set out policies to diversify its energy supply chains from reliance on Russian gas supply on the one hand and on China for solar panel manufacture on the other. These objectives are articulated in the EU's REPowerEU Plan[8] and related strategies including the Green Deal Industrial Plan[9] and EU Solar Strategy[10]. Equally, the European Solar Photovoltaic Industry Alliance (ESPIA) has as one of its objectives to maintain international partnerships and ensure resilient global supply chains. The EU's Green Hydrogen Strategy links gas and solar PV diversification, as the shift to green hydrogen and derivative products is likely to generate enormous demand for investment in solar PV.

The EU has also set out ambitions to build more ethical supply chains through the Corporate Sustainability Due Diligence Directive and Solar Stewardship (CSDDDSS) initiative with a focus on

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[6] R Davies, *Navigating New Turbulences at The Nexus of Trade and Climate Change: Implications and Options for Africa*, Africa (2022), https://africanclimatefoundation.org/news_and_analysis/navigating-new-turbulences-at-the-nexus-of-trade-and-climate-change/#elementor-action%3Aaction%3Dpopup%3Aopen%26settings%3DeyJpZCI6IjM4ODMiLCJ0b2dnbGUiOmZhbHNlfQ%3D%3D.

[7] International Energy Agency, *Special Report on Solar PV Global Supply Chains* (2022), https://iea.blob.core.windows.net/assets/d2ee601d-6b1a-4cd2-a0e8-db02dc64332c/SpecialReportonSolarPVGlobalSupplyChains.pdf.

[8] European Commission (2019). "REPowerEU: Affordable, secure and sustainable energy for Europe," European Commision, accessed 16 October 2023, 2023, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en.

[9] Europa (n.d.) "The Green Deal Industrial Plan: putting Europe's net-zero industry in the lead," European Commission, accessed 16 October 2023, 2023, https://ec.europa.eu/commission/presscorner/detail/en/ip_23_510.

[10] European Commission (n.d.) "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: EU Solar Energy Strategy," European Commission, accessed 16 October 2023, 2023, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2022%3A221%3AFIN&qid=1653034500503.

value chains that are environmentally responsible, respect human rights and offer decent labour conditions.[11]

This statement of intent aligns with the recognition that climate change has a disproportionately negative impact on vulnerable groups. Climate change is expected to increase poverty owing to effects on agriculture, flooding, malnutrition, water resources and health.[12] Poor households already struggle to access energy resources in South Africa which exacerbates poverty and women's marginalization. Furthermore, it is likely to deepen pre-existing inequalities if mitigation and adaptation strategies do not reduce energy poverty and directly or indirectly improve opportunities for wage employment and entrepreneurial involvement.

Significant attention is being placed on promoting Gender Equality and Social Inclusion (GESI) in climate mitigation and adaptation programmes as well as part of moving to meet the Sustainable Development Goals (SDGs). The EU has taken several steps to include women in the solar PV value chain. Women account for 40 percent of the solar PV workforce, which is more than double the share of women employed in the wind industry (21 percent) and the oil and gas sector (22 percent). Women do best in solar PV manufacturing, where they represent 47 percent of the workforce, followed by service providers and developers at 39 percent and 37 percent. Women Solar PV installers represent only 12 percent of the workforce. [13] For off-grid solar PV however, women both deliver solutions and are beneficiaries at the same time. In South Africa, policies are in place to support inclusion of women, especially black women, but this has not yet resulted in significant participation along the value chain. Any integration of the solar PV chains between the EU and South Africa will need to develop a specific and measurable inclusion programme for women in the industry to ensure gender inclusivity.

1.2.2. The state of and outlook for global solar PV deployment

The global solar PV market deployed a record 239GW in 2022 with SolarPower Europe forecasting annual growth of between 15 percent and 17 percent from 2023 to 2027. Annual installation is estimated to almost triple to 617GW in 2027.[14] Global solar PV manufacturing capacity is dominated by China, which has invested heavily in the entire value chain over the last decade. When averaged over the chain, China's share of the entire solar PV value chain exceeds 80 percent with most of this share growth having been acquired from Japan, the EU, and the US.[15] Supply on all elements shifted from 2010 where China took significant share from Europe, Asia Pacific (APAC) and North America and reduced the cost of acquiring solar PV by an estimated 80 percent relative to other producers over the same period.

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[11] SolarPower Europe (n.d.) "EU Corporate Sustainability Due Diligence Directive," SolarPower Europe, accessed 16 October 2023, 2023, https://www.solarpowereurope.org/advocacy/position-papers/eu-corporate-sustainability-due-diligence-directive.

[12] United Nations Framework Convention on Climate Change, *United Nations Climate Change Annual Report 2022* (2022), https://unfccc.int/sites/default/files/resource/UNClimateChange_AnnualReport_2022.pdf.

[13] IRENA (2022). Solar PV Employs More Women Than Any Renewables.

[14] SolarPower Europe, *Global Market Outlook for Solar Power 2023-2027* (2023), https://www.solarpowereurope.org/insights/outlooks/global-market-outlook-for-solar-power-2023-2027#download.

[15] IEA (2022), *SPV Global Supply Chains*, IEA, Paris https://www.iea.org/reports/solar-pv-global-supply-chains, License: CC BY 4.0

The African Solar Industry Association (AFSIA)[16] and the International Renewable Energy Agency (IRENA)[17] both record that approximately 1GW of capacity was installed in South Africa in 2022. These estimates are contested and seem to underestimate the level of South African solar PV installation. South African data show that from 1 Nov 2013 to 31 Dec 2022, 2,287 MW of largescale solar PV and 500 MW of Concentrating Solar-thermal Power (CSP) became operational and that in 2022, 75 MW of solar PV was added to the grid.[18] Further, in 2022, SAPVIA reported at least 1 GW of installed capacity- with this data supported by SAPOA. SAPVIA data also note that installed capacity estimates an approximate 700MW increase in installed capacity from Q4 in 2022, to Q1 2023. The rapid growth in solar PV installations in South Africa in 2022 and 2023 has been driven by a confluence of circumstances and policy shifts elaborated on below.

1.3. The state of and outlook for global solar PV manufacturing

The solar PV manufacturing value chain is comprised of three main segments. The upstream segment involves the production of polysilicon, and its processing into silicon ingots and wafers. The midstream segment transforms the wafers into cells which in turn are assembled into solar PV modules. The downstream and (side-stream) segments include the production of various other solar PV subsystems including mounting structures and trackers, cables, and combiner boxes; inverters; and components for the electrical BoP.

Silicon is a crucial element essential to produce solar PV ingots and wafers. It is produced from metallic grade silicon (SiO_2), which is found in the form of quartz or sand. Silica is extracted and refined into pure silicon, and subsequently electronics grade silicon for use in solar PV and semiconductors. The amount of metallurgical-grade silica deposits in South Africa is significant. Deposits of variable grade are found in various locations such as Kwa-Nibela, Mmbazwana, Fernwood, and Mtubatuba in the Lower Umfolozi District (KwaZulu-Natal). The Silica Quartz mine, located outside Delmas, has been supplying high-grade silica sand and grit to various industries, including the metallurgical industry, since 1972. Silica is used in additional applications, glass, construction, filter media, ceramics, and metal casting.

China overwhelmingly dominates both the upstream and midstream segments of solar PV manufacturing, underpinned by extensive state support. Globally, it is the leading producer of silicon and downstream ingots and wafers, with an estimated 91 percent global market share in wafers in 2021. Other important producers are the US, Brazil, and Australia. South Africa has substantial deposits of appropriate grade silica but has no silica processing capability.

Production of polysilicon is dominated by some major global producers (some of whom supply both the semiconductor and solar PV markets). The largest producers are Chinese and include GCL-Poly, Tongwei Group, Xinte Energy and Dako New Energy Corp, all based in China; Wacker

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[16] African Solar Industry Association, *Annual Solar Outlook 2023: A country-by-country review of the status of solar energy in Africa* (2023), http://afsiasolar.com/wp-content/uploads/2023/01/AFSIA-Annual-Outlook-Report-2023-Full-digital-final_compressed-1.pdf.

[17] International Renewable Energy Agency (IRENA), (2023). *Renewable energy statistics 2023*. Renewable energy statistics 2023 (irena.org)

[18] CSIR Energy Centre (2023). *Statistics of utility-scale power generation in South Africa.* *https://www.csir.co.za/sites/default/files/Documents/Statistics%20of%20utility-scale%20power%20generation%20in%20South%20Africa_2022H1.pdf*

Chemie AG with facilities in Germany and the US; and OCI in South Korea and Malaysia; and REC silicon in the US and Norway.[19]

The production of polysilicon is highly energy intensive with Chinese production heavily reliant on coal-based power.[20] Efforts are underway to increase energy efficiency and reduce environmental impacts through more efficient reactors, optimizing processes, and investing in renewable energy. Green or significantly greener production of polysilicon at competitive pricing would represent a breakthrough. As discussed below, production of greener polysilicon could be an opportunity for South Africa.

Over the decade 2010 to 2021 China has established a formidable lead in the midstream segment- the manufacturing of solar PV panels and modules. Between December 2009 and December 2022, the cost of crystalline solar PV modules sold in Europe declined by 91 percent.[21] [22] China has continued to invest in solar PV manufacturing, adding 40-50 percent of capacity in wafers,[23] cells and modules in 2022 and doubling polysilicon capacity despite capacity utilisation levels of existing plants at between 20 percent and 40 percent. The International Energy Agency (IEA) (2023, p55) therefore anticipates short term oversupply with "new manufacturing investments in India, the United States and Europe … [contributing] … to the supply glut". [24]

Three main jurisdictions are challenging China's lead in upstream and midstream solar PV production and have put or are busy putting in place large-scale industrial policy support measures to do so: the United States, Europe, and India. Both the US and the EU have stated their intention to reduce their reliance on China for strategic inputs required for the green energy transition and digital economy[25]. The bulk of announced investment in solar PV manufacturing capacity outside of China in 2022 and 2023 is from these three jurisdictions. The IEA estimates that by 2027 additional capacity of at least 20GW will be established in each of these three regions. Chapter 3 elaborates on recent and emerging policy support measures being put in place by the US, EU, India, and Türkiye.

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[19] Faisal, R. (2023). *Polysilicon market trend: a look into the growing demand for solar energy.* https://www.linkedin.com/pulse/polysilicon-market-trend-look-growing-demand-solar-energy

[20] https://www.ft.com/content/ca7283a3-53e6-4066-a9f9-91adb3cf8d2b; https://www.wsj.com/articles/behind-the-rise-of-u-s-solar-power-a-mountain-of-chinese-coal-11627734770

[21] International Renewable Energy Agency, *Renewable power generation costs in 2022* (2023).

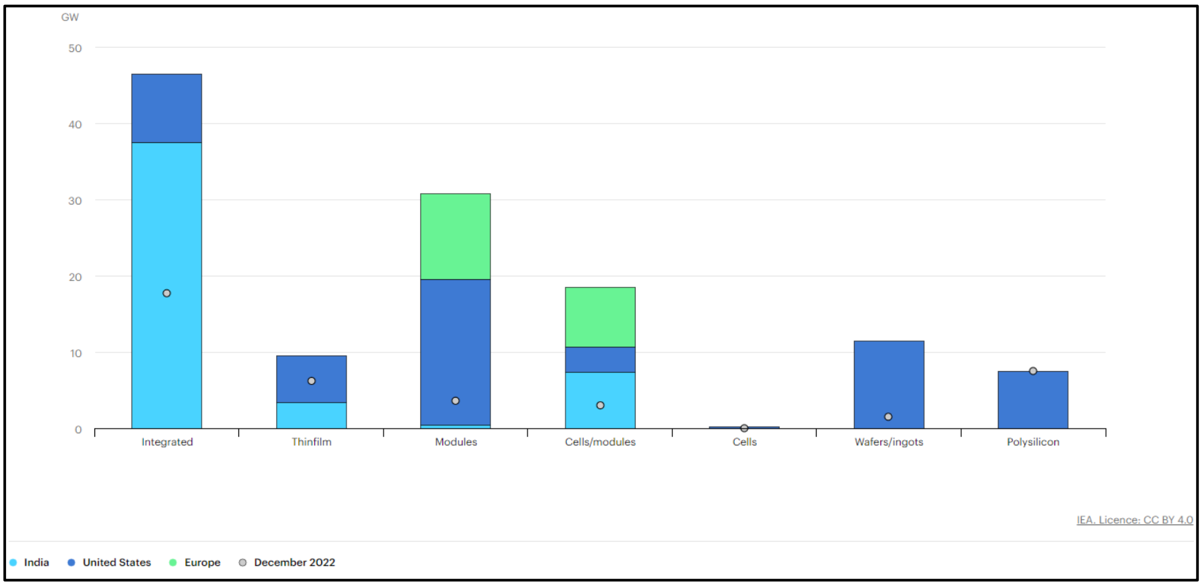
[22] International Energy Agency, *Special Report on Solar PV Global Supply Chains*.

[23] PV magazine (2023). *China mulling restrictions on polysilicon, wafer production tech exports.* China mulling restrictions on polysilicon, wafer production tech exports – pv magazine International (pv-magazine.com)

[24] International Energy Agency, *Renewable Energy Market Update: Outlook for 2023 and 2024* (2023), https://iea.blob.core.windows.net/assets/63c14514-6833-4cd8-ac53-f9918c2e4cd9/RenewableEnergyMarketUpdate_June2023.pdf.

[25] Kaya, *Race to the top on clean energy – The US and EU response to China's dominance*, Principles for Responsible Investment (2023), https://www.unpri.org/download?ac=17824.

Figure 1: Announced solar PV manufacturing capacity by region and component, 2022-2023[26]



Source: IEA, 2023

Note: Integrated facilities include most or all the upstream and midstream processes from production of polysilicon through to panels and modules, within a single facility.

Chinese manufacturers are investing in expanding wafer, cell, and module manufacturing in Southeast Asia. Additionally, manufacturing plants will open in India and the United States due to new industrial policies introduced last year. India has developed the production-linked incentive (PLI) scheme, and the US Inflation Reduction Act (IRA) has led to a surge in new solar manufacturing projects. Between November 2022 and May 2023, announcements for projects indicated the potential for national supply chains with over 20 GW of capacity in each region. In Europe, new manufacturing capacity accounted for just 14 percent of the announced projects as from August 2022. The EU Green Deal Industrial Plan and the Net-Zero Industry Act are aiming for Europe to produce 40 percent of its solar PV targets by 2030, but specific incentives are not currently included. High prices of industrial energy have also increased the cost of manufacturing solar PV equipment in EU countries.[27]

The cost of energy has been highlighted as the main barrier to cost competitiveness for the manufacture of solar PV in the EU, with calls inter alia for industrial policy support to accelerate the adoption of higher energy efficiency technologies. With raw material availability in South Africa and much higher radiation levels of solar energy, this presents an opportunity to explore collaboration between South Africa and Europe.

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[26] IEA (2023). *Announced SPV manufacturing capacity by region and component, 2022-2023*, IEA, Paris https://www.iea.org/data-and-statistics/charts/announced-solar-pv-manufacturing-capacity-by-region-and-component-2022-2023, IEA. Licence: CC BY 4.0 International Energy Agency, "Announced solar PV manufacturing capacity by region and component, 2022-2023." https://www.iea.org/data-and-statistics/charts/announced-solar-pv-manufacturing-capacity-by-region-and-component-2022-2023.
[27] Molina, P.S. (2023). Global PV manufacturing capacity to reach 1 TW by 2024 – pv magazine International (pv-magazine.com)

Production of other solar PV componentry also requires a range of minerals and processing into metals and other intermediate materials. South Africa has substantial deposits of many of these.

Table 1: Minerals and intermediate materials required for solar PV sub-system components.

Final products	Minerals	Materials & Metals	Components
PV Panels	Silica	Glass Polysilicon	Crystalline silicon cell
	Silver	Silver paste	Super substrate glass
	Petroleum Oil	Synthetic Polymers	Laminate
	Zinc	Solar cells	Ethelene vinyl acetate
	Indium		Backing sheet
	Gallium		Copper ribbon wiring
Mounting structures and cabling	Selenium	Steel Aluminium	Steel/Aluminium profiles
	Cadmium		Clamps and rails
	Tellurium		Nuts and bolts
	Zinc		Cabling
	Copper		Conductors
	Aluminium		Insulation
	Limestone		Armour
	Iron		Direct current cable connectors
Inverters	Molybdenum		Enclosures
	Chromium	Steel	Transformers
	Manganese		Electronics
	Nickel		Circuit boards

Source: USAID, 2022

1.4. Domestic context

1.4.1.The initial development of the South African solar PV supply chain

The initial development of the South African solar PV market has been driven by utility scale public procurement of renewables through the 2011 REI4P. The 2019 IRP envisages procurement of 22.9GW of renewables and battery storage between 2022 and 2030, of which 6.4GW is solar PV.[28] The current IRP reflects 7958MW or 10.5 percent to be solar PV by 2030. State owned banks such as the IDC and the Development Bank of Southern Africa (DBSA) played an important role in co-financing early REI4P projects in tandem with the private sector[29] and the IDC has also funded manufacturing projects linked to the REI4P. As elaborated below, a number of these projects have closed due to uncertainties related to policy and implementation of the REI4P. Although the IRP is

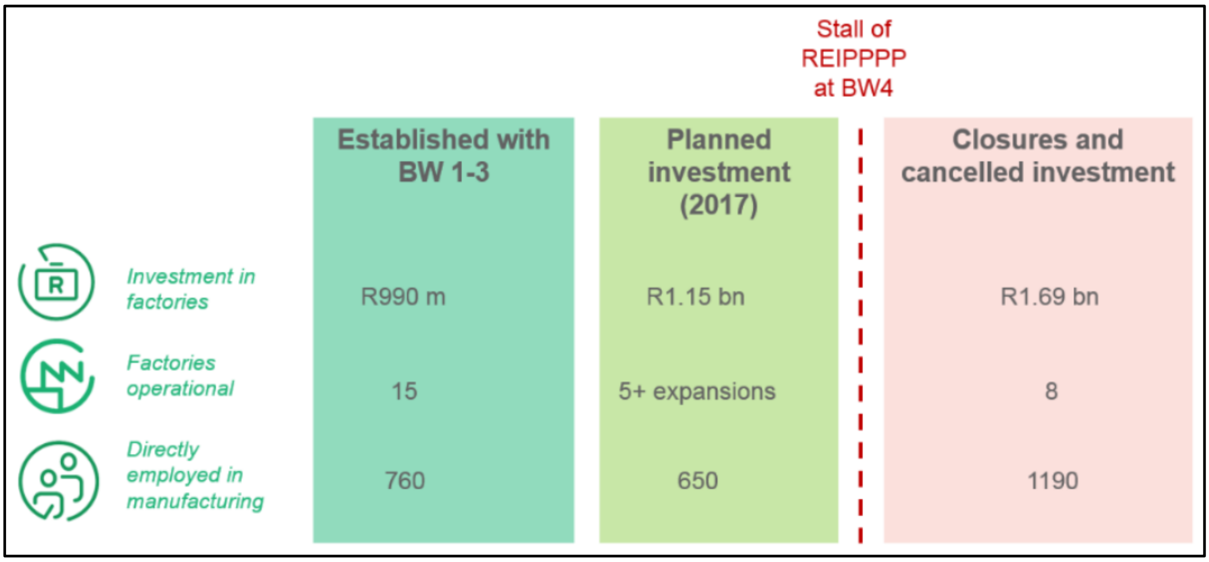
[28] Government of South Africa, *South African Renewable Energy Masterplan (SAREM): An industrial and inclusive development plan for the renewable energy and storage value chains by 2030 (Draft version for review 7 July 2023)* (7 July 2023 2023), https://www.dmr.gov.za/Portals/0/Resources/Renewable%20Energy%20Masterplan%20(SAREM)/South%20African%20Renewable%20Energy%20Masterplan%20(SAREM)%20Draft%20III.pdf.
[29] Christine Juta and Wikus Kruger, "How SA's financial sector supercharged renewable energy," *Business Day*, 25 July 2022 2022, https://www.businesslive.co.za/bd/opinion/2022-07-25-how-sas-financial-sector-supercharged-renewable-energy/.

supposed to be revised every two years, no updates since 2019 have been published. However, an updated IRP is due to be published before the end of 2023.

Local content requirements in REI4P projects, although initially modest, provided an initial stimulus to the development of parts of the South African solar PV value chain. While Bid Windows (BWs) 1 to 3 proceeded smoothly, albeit with limited local content, further rollout of the REI4P has been undermined by uncertainty and delays which have undermined both more rapid installation of renewable energy and, to an even greater extent, the conditions for localisation linked to the REI4P. Particularly damaging was "stop-start" procurement between 2015 and 2019, especially under bid-windows 4 and 5. Further uncertainty was engendered by long delays by Eskom in concluding Power Purchase Agreements (PPAs). Uncertainty and delays led to the closure of a number of manufacturing facilities that setup in anticipation of the smooth rollout of the REI4P. The March 2022 draft of the SAREM estimated that ZAR1.69bn in investment closures and cancellations took place, with 8 factories closed or cancelled and 1190 jobs foregone (

Figure 2).

Figure 2: Closures and cancelled investments associated with BW4 delays.



Source: SAREM (2022), p74

Meanwhile, as a response to low levels of 'meaningful' local content in 2016, the dtic significantly increased the levels of local content by designating far more ambitious levels of local content for various sub-systems in terms of the Preferential Procurement Policy Framework (PPPF) (Table 2).[30,,31]

Table 2: Minimum local content thresholds for solar PV components, 2016

Solar PV components	Minimum Local Content Threshold	Conditionality
Laminated PV Modules	15%	The local process will include tabbing and stringing of cells, encapsulation and lamination,

[30] Interviews with DTIC officials, 2023
[31] National Treasury Instruction Note Number 2 of 2016/17 in terms of Preferential Procurement Regulations, 2011.

Solar PV components	Minimum Local Content Threshold	Conditionality
		final assembly, and testing in compliance with IEC Standards
Module Frame	65%	Aluminium Components: All aluminium PV Module Frames, PV mounting structures/racks, clamps, brackets, foundation components and fasteners are to be manufactured from locally produced extruded, rolled, cast, or forged products.
DC Combiner Boxes	65%	DC Combiner Boxes: Enclosures must be made from SMC and moulded in South Africa.
Mounting Structure	90%	All aluminium PV Module Frames, PV mounting structures/racks, clamps, brackets, foundation components and fasteners are to be manufactured from locally produced, extruded, rolled, cast, or forged products
Inverter	40%	Must be assembled locally

Source: National Treasury, 2016

Notwithstanding the negative impact of policy uncertainty and delays, some progress has been achieved with local content in the first five bid windows, with a reported increase from 34 percent under BW1 to 44 percent under BW5[32] and important capabilities developed that form a basis on which to build. As at the end of March 31, 2023, ZAR64,8 billion had been spent on local procurement representing 49 percent of total project value for all RE projects.[33]

1.4.2.Recent policy developments

The review of major research conducted since the publication of the baseline study, indicate that there have been considerable policy changes, and to a lesser extent in the structure of the domestic industry.

Between 2011 and 2021 renewable projects, including solar PV were overwhelmingly driven by public procurement under the REI4P. However, since 2019, regulatory reforms began to open greater participation for private sector renewable projects. These reforms have in large part been in response to the escalation of loadshedding to unprecedented levels.[34] In 2019 independent power projects[35] between 1MW and 10MW were exempted from obtaining licencing approval from the National Energy Regulator of South Africa (NERSA), subject to a cap of 500MW of such projects per annum. In August 2021, the ceiling on projects requiring NERSA approval was raised to 100MW and removed entirely in December 2022.[36]

However, localisation linked to the REI4P is subject to uncertainty on two fronts. First, substantial investment is required in expanding the national grid to feed in electricity from the 'three Capes': the Northern, Western and Eastern Cape. These provinces are where the bulk of South Africa's

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[32] GreenCape (2023). *Large Scale Renewable Energy Market Intelligence Report*. https://greencape.co.za/wp-content/uploads/2023/04/RENEWABLE_ENERGY_MIR_2023_DIGITAL_SINGLES.pdf
[33] Independent Power Producers Procurement Programme (IPPPP). (2023)
[34] Loadshedding is the South African term for electricity blackouts.
[35] This refers to private sector led projects. Most RE projects in South Africa are independent of government
[36] SAPVIA (2022) South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

solar and wind resources are located and hence most renewable projects. Second, the applicability of local content designations has been thrown into uncertainty due to a Constitutional Court judgement which found the Preferential Procurement Policy Framework Act (PPPFA) unconstitutional. In June 2023, the Minister of Finance introduced a revised Public Procurement Bill to Parliament. Unlike the PPPFA and its regulations the Bill proposes that there are no pre-qualification criteria (such as local content) in public procurement and that any non-price public policy considerations are capped at an effective 10 percent. If the Bill is promulgated in its current form this will severely water down any local content requirements under the REI4P unless the IPP office secures a deviation from National Treasury from the new Act.

It remains unclear whether revised legislation being developed by National Treasury and regulations to be issued in terms of this legislation will continue to embed local content requirements and in what form.

Two additional policies will have a bearing on the solar PV sector. A Green Hydrogen Commercialisation Strategy was released for public comment in November 2022 and was approved by Cabinet in October 2023. It is expected to be finalised and formally released by the end of 2023. If a large-scale green hydrogen industry does emerge in South Africa, it will require enormous investment in solar PV in particular.[37] The long anticipated New Energy Vehicle policy, pencilled in to be launched at the end of October 2023, is likely to generate considerable demand for renewable investment.

The implementation of the African Continental Free Trade Agreement (AfCFTA) may also present significant opportunities for South Africa's solar PV manufacturing industry. While the market in the rest of Africa is not the largest or most rapidly growing it is anticipated to expand and could provide an important source of demand. South African manufacturers could benefit from preferential market access to certain countries and sub-regions on the continent.

The confluence of these policy reforms has contributed to considerable growth in both the large-scale private project pipeline and SSEG rooftop solar installations for the commercial, industrial, and residential markets.

1.5. The state of and outlook for South African Solar PV deployment

SAPVIA estimates that 5.7GW of operational solar PV has been installed in South Africa by the end of the first quarter of 2023 (Table 3).[38] Of these publicly procured REIPPPP projects account for 2,29GW (40 percent) and private projects 3.37GW (60 percent).3.79GW (67 percent are utility scale or large-scale and 1.87GW (33 percent) SSEG projects. [39]

Table 3: Cumulative installed solar PV capacity at end Quarter 1 2023, (MW)

Market Segment	System Size	Installed Capacity (MW)
Residential	0 – 30kWp	620.9
C&I SSEG	30kWp – 1MWp	1247.7
C&I Large Scale and US	1MWp – 50MWp	1925.5

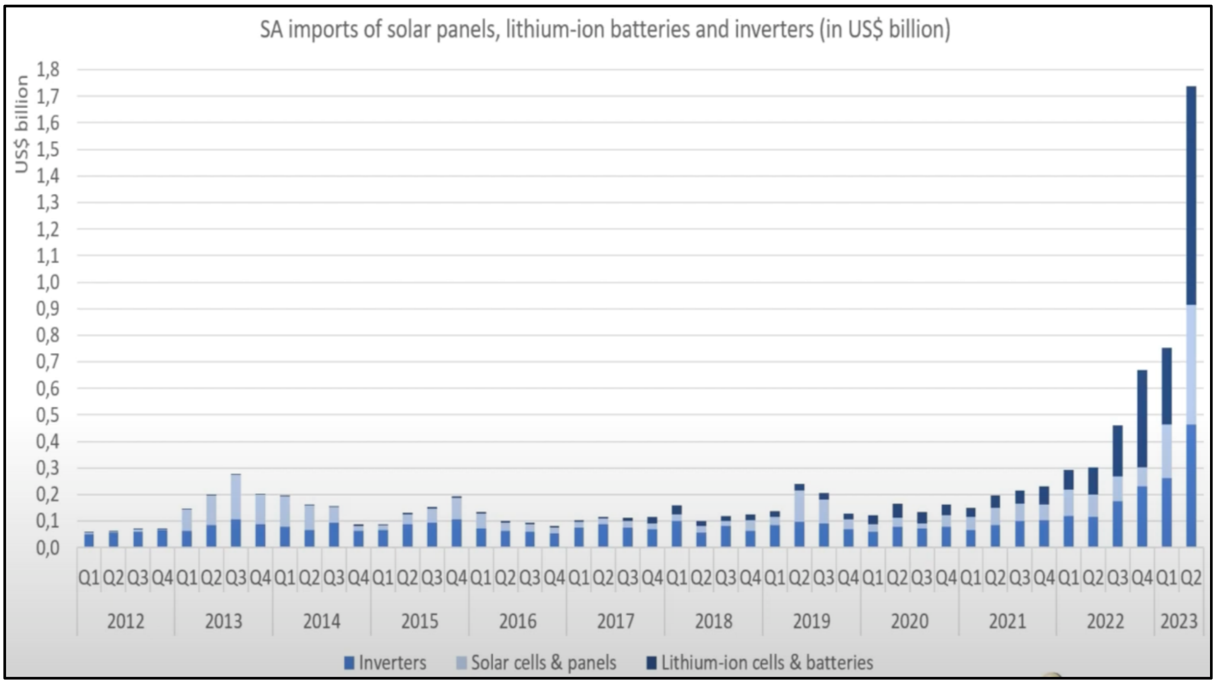
[37] The dtic (2022). *Green Hydrogen Commercialisation Strategy.* http://www.thedtic.gov.za/green-hydrogen-commercialisation-strategy/
[38] SAPVIA (2023) *Solar PV Installed Capacity Data Dashboard*. https://sapvia.co.za/dataportal/dataportal-public
[39] Authors' calculations based on SAPVIA 2023 and personal communication, De Wet Taljaard, 20 October 2023.

Market Segment	System Size	Installed Capacity (MW)
Utility scale	> 50MWp	1865.0
Total		***5659.1***

Source: SAPVIA, 2023

The combination of unprecedented levels of loadshedding, relaxation of licencing requirements for private projects and a tax incentive for the installation of rooftop solar systems[40] has contributed to a dramatic increase in the installation of commercial, industrial, and residential rooftop solar. This is reflected in the large increase in imports of panels, batteries, and inverters for solar PV installations in 2022 and the first half of 2023. Estimated South African rooftop solar PV capacity increased[41] from 983MW in March 2022 to 4,4GW in June 2023, an increase of 349 percent.[42] These figures need to be reconciled with those collected by SAPVIA. There is likely to be some overlap of solar PV imports across large and SSEG installations.[43]

Figure 3: SA Imports of Panels, Batteries, and Inverters for solar PV Installations.



Source: Montmasson-Claire, 2023

According to an Eskom survey jointly conducted with SAPVIA and the South African Wind Energy Association (SAWEA), approximately 66GW of renewable projects are reported to be at various stages of development including some 32GW of solar PV.[44] This study was aimed at utility scale

[40] National Treasury (2023)
[41] All private sector projects, rooftop, ground mount C&I and utility scale.
[42] Energy Monitor (2023). *South Africa's unprecedented rooftop solar boom*. [South Africa's unprecedented rooftop solar boom (energymonitor.ai)]
[43] The ESKOM data set and SAPVIA installed capacity data are within 5% at the end of Q1 2023 for all non-REIPPPP installations.
[44] Engineering News (2023). *Renewable Energy Grid Survey points to 66 GW development pipeline in South Africa.* https://www.engineeringnews.co.za/article/renewable-energy-grid-survey-points-to-66-gw-development-pipeline-in-south-africa-2023-06-06

projects that would connect at ESKOM transmission level only. [45] A 32GW project pipeline may be optimistic due to the possibility of duplication of projects and inclusion of projects which are only at expression of interest stage. The actual pipeline may be closer to 13GW.[46] On the other hand 32GW appears to exclude significant parts of planned SSEG rooftop solar installation due to weak general enforcement of the obligation of SSEG projects to register with municipal authorities.[47] Bid rounds 5 and 6 of the REI4P of 2.5GW are still in the pipeline with 10GW to be awarded under rounds 7 and 8.

An additional perspective and projection of the project pipeline is expected to emerge from research currently underway on behalf of the SAREM.[48] The release of the long-awaited update to the 2019 IRP will also bring greater clarity with respect to the solar PV project pipeline over the next decade.

However, the overall picture is of a sustained and substantial growth in both publicly and privately procured solar PV over the next decade and longer. For South Africa to meet its nationally determined contributions by 2050 it will have to install an estimated 89GW of solar PV by 2050, a net increase of over 83GW relative to what has already been installed.[49]

[45] The survey directly impacts the GCCA and the TDP as such, the SAREGS explicitly captures short and medium term private sector demand to inform the necessary transmission network developments required to connect the additional capacity. The level of project readiness is captured by the project type, A, B and C. details are explained on the SAREGS results slides.
[46] Personal communication, Montmasson-Claire, 29 September 2023.
[47] South African Local Government Association (SALGA) (2018). *Municipal Legal Framework Applicable to Small-Scale Embedded Generation.* https://www.sseg.org.za/wp-content/uploads/2019/03/Municipal-SSEG-Legal-Framework.pdf
[48] Personal communications SAREM and Localisation Support Fund (who are funding the study).
[49] Bryce Mccall et al., *South Africa's power generation future in the context of the Paris Agreement*, Energy Systems Research Group, University of Cape Town (2020), https://ebe.uct.ac.za/sites/default/files/content_migration/ebe_uct_ac_za/1135/files/2020_Paper%25209%2520Mccall%2520-%2520South%2520Africas%2520electricity%2520planning%2520in%2520context%2520of%2520the%2520Paris%2520Agreement.pdf.

2. Updated industry map

2.1. Introduction

Since the 2021 USAID baseline study there have been significant changes to the South African solar PV market, and to a lesser extent to the structure of South African solar PV manufacturing. The most comprehensive recent study of the solar PV industry is the SAPVIA commissioned report concluded in October 2022.[50] Deployment of solar PV has grown substantially in South Africa since between 2011 and 2021and even more rapidly on the continent, albeit off a very low base: from 0.01GW to 5.7GW and 0.27 to 10.3GW, respectively. SAPVIA forecasts that between 12 and 24.2GW of solar PV could be added by 2030. As discussed in Chapter 1 various regulatory reforms have accelerated the growth of private projects while REI4P projects continue to be a major source of demand.

The SAPVIA report estimates that approximately 20,000 people are employed in the industry (on a full-time equivalent basis), overwhelmingly in the construction and installation parts of the value chain and approximately 3,000 in domestic manufacturing and 3,000 in project development. Applying the World Bank indirect job multiplier of 3.8 jobs created for every manufacturing job created[51], suggests that solar PV manufacturing jobs have created or support 11,400 jobs in other sectors of the economy.

Due to a variety of factors including policy uncertainty, delays, and limited support measures to attain economies of scale, the growth in demand for solar PV sub-systems and components has overwhelmingly been serviced by imports rather than domestic production. Over 120 retailers are well-established in the South African market, predominantly supplying imported componentry.

By contrast there are a limited number of dedicated solar PV domestic manufacturers, between 30 and 40, often supplying a limited proportion of the domestic market. This analysis and industry interviews conducted suggest that there has been limited growth in South African manufacturing capacity to service substantial, albeit uneven, increases in demand. However, important manufacturing capacity has been established in several sub-systems and components which could form the basis for further expansion and value chain integration. These include to varying degrees module assembly, mounting, and tracking structures, cabling switchgear, inverters, combiner boxes and charge controllers. While battery storage is becoming an increasingly important part of systems of solar PV installation at both the utility and SSEG scale, consideration of battery storage is beyond the scope of this report.

[50] United States Agency for International Development, *South African Solar PV Value Chain: Analysis and Strategies for Increasing Localization*.
[51] World Bank Group, *Focus on Private Investment for Job Creation* (January 2017 2017), https://documents.worldbank.org/curated/en/509111484323988058/pdf/111888-WP-PUBLIC-jan-17-4-am-WB-Econ-Update-version4.pdf.

2.2. The structure of the South African solar PV value and supply chains

Figure 4 provides a detailed overview of the structure of the South African solar PV value chain, including the main minerals; materials and metals; sub-systems and associated components, whether produced domestically or embodied in imports.[52]

2.2.1.Minerals, materials, and metals

Most of the minerals required to produce solar PV components and assemble them into sub-systems are found in South Africa or elsewhere on the continent. However, the presence of these raw materials does not automatically translate into downstream processing for the solar PV value chain.

While South Africa has significant deposits of silica, this is not currently processed into polysilicon needed for silicon ingots, wafers and cells, the fundamental building blocks of solar panels. As discussed below this is a significant area for analysis and pre-feasibility studies. Some rare earths needed for PV cells are mined in South Africa including Indium, Gallium, Selenium, Cadmium and Tellurium. These are often by-products of base metal ore mining and processing.

South Africa holds deposits of minerals essential to produce carbon steel and stainless steel, notably iron ore, manganese, chromium, and nickel. While these are essential inputs, solar PV applications form a small proportion of overall demand for most of these inputs. This is similarly the case for polymers produced from coal, and aluminium produced from (imported) bauxite.

While South Africa produces steel, aluminium and polymers from upstream feedstocks, downstream manufacturers do not necessarily enjoy any price advantage due to the practice of import-parity pricing. Furthermore, due to past demand uncertainties some downstream manufacturers such as aluminium extruders have been reluctant to commit to investments required to produce, for instance, frames required for solar PV modules.[53] As the review of the international solar PV manufacturing market investment in the development of manufacturing capabilities at scale is the most important determinant of competitiveness in the value chain. However, the presence of certain raw materials can provide a potential advantage, as elaborated on with respect to the possibilities of transforming South Africa's silica deposits into polysilicon and further value chain development.

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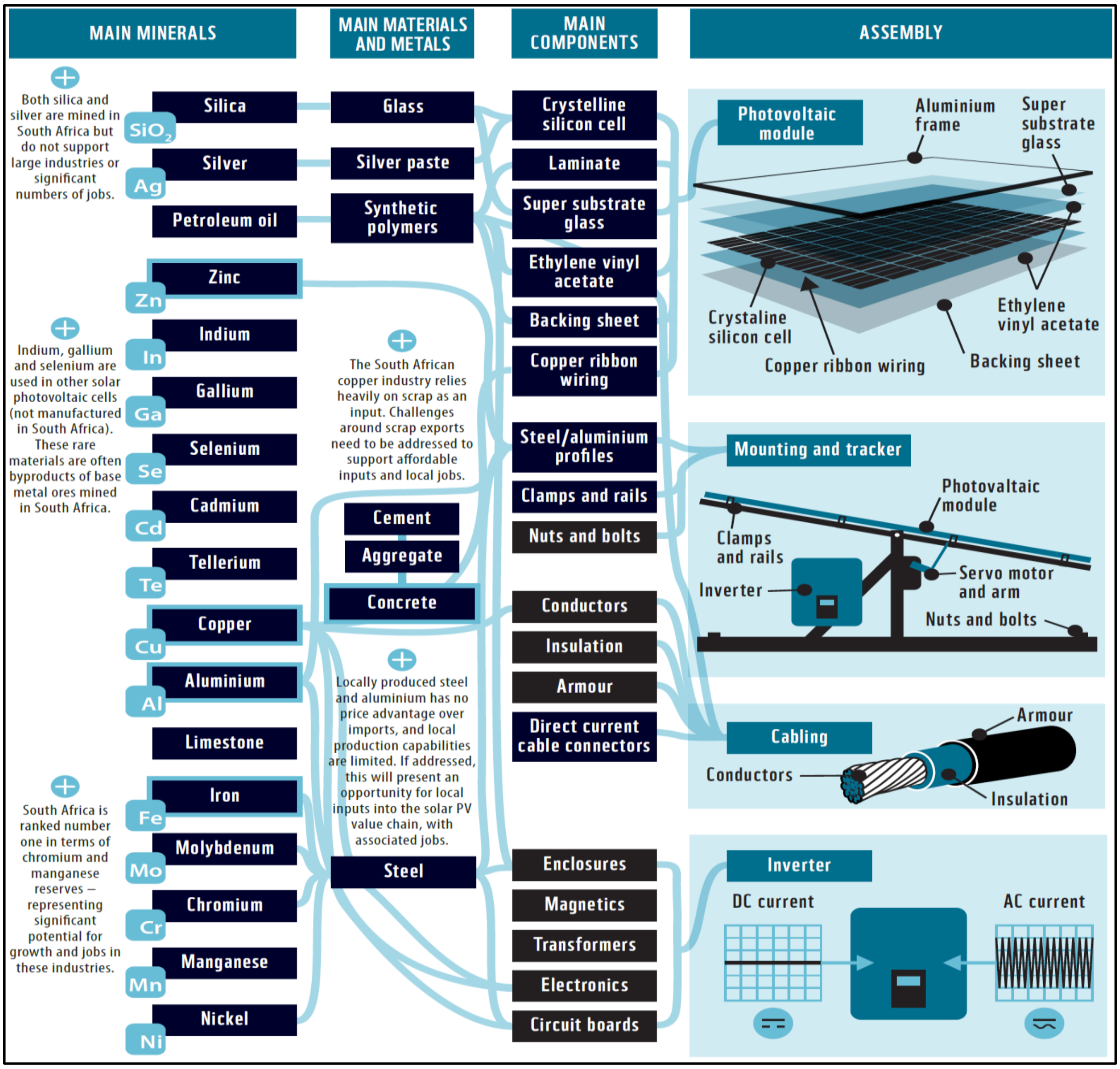
[52] Kate Rivett-Carnac, *Insights into the Solar Photovoltaic Manufacturing Value Chain in South Africa*, Trade and Industrial Policy Strategies (2022), https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/download/2318_580a29341ebed848aa5e5656b6852f2b.

[53] Interview, Montmasson-Claire (2023)

Figure 4: Materials and manufacturing value chain for solar PV – Opportunities for South Africa



Source: Rivett-Carnac (2022), design by WWF.[54]

2.3. Structure of South Africa's solar PV supply chains

The bulk of solar PV components are imported, predominantly from China but also from Europe. This is particularly the case for major components: PV modules and inverters with a 10 to 15 percent local market share. Domestically produced components with local market share of 50 percent or above include combiner boxes, cables (LC), trackers and monitoring, switchgear, transformers, conduits, and fittings. Charge controllers and circular breakers and surge protection devices each have 30 percent domestic market penetration (Table 4).[55]

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[54] Rivett-Carnac, *Insights into the Solar Photovoltaic Manufacturing Value Chain in South Africa*.
[55] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

Table 4: Summary of local solar PV manufacturing capacity

Components	Locally manufactured brands	Jobs	Domestic Market Penetration
Solar PV modules	2	50 - 100	<15%
Inverters	4	190 - 210	10%
Mounting racks	7	500 - 600	<5%
Combiner boxes	3	650 - 700	75%
Cables	3	50 - 70	5% (solar cables); 75% (LC cables)
Trackers and monitoring	5	250 - 300	75%
Charge controllers	<5	100 - 150	30%
Switchgear	4	400 - 450	50%
Circular breakers and surge protective devices (SPD)	2	10 - 20	30%
Transformers	9	500 - 600	50% (solar); 65% (MV)
Conduits and fittings	7	200 - 220	75%

Source: SAPVIA (2022)

Two main factors are identified as predominant constraints to further growth of domestic solar PV manufacturing. First, the commoditization of major components and the need to attain economies of scale to compete with imports. This in turn is partly a function of certainty of demand and partly the need for large-scale investment and re-investment, particularly in solar PV modules. Second, the requirement by project developers and Original Equipment Manufacturers (OEMs) for compliance with warranties linked to international standards in large scale projects and 'softer' brand awareness and assurances of reliability in the SSEG markets. Addressing skills shortages and development is also important, as is the availability of metal and plastic materials at competitive pricing and through investments to fill value chain gaps (such as certain extruded aluminium products).[56]

As discussed, the main source of demand for utility scale solar has been government procurement in terms of IRP targets and implemented via the REI4P. Development of a large-scale project pipeline has been driven by a combination of unprecedented levels of loadshedding, relaxation and ultimate removal of licensing requirements and greater scope for grid wheeling agreements. The SAPVIA study estimates market potential by 2030 as an additional 6 - 10GW in IRP/REIPP driven Utility scale; 2 - 5GW in Commercial and Industrial; 1.5 – 3.9GW in Mining, 1.4 – 2.1GW in Agriculture; and 1.1GW – 3.1GW in residential segments. This may have been an underestimate given the current pipeline even if the lowest estimate in the recent survey range is taken into account. However, this aggregates to between 13GW and 23GW additional solar PV installation by 2030. The low end of this range, 13GW, equates to close to the 2GW average installation per annum required to establish economies of scale for the supply to the domestic market. Supplementation of domestic demand with exports to the rest of the continent and into the EU would further enhance conditions for the attainment of scale. However, it is important to distinguish between sub-systems as the minimum scale for solar PV panel production is likely to be much higher.

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[56] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

There is a close correspondence between SAPVIA's (2022) and the most recent SAREM's (2023) views on localization potential in major solar PV sub-systems as set out in Figure 5.

Figure 5: Localisation opportunities based on SAREM and SAPVIA Scenarios

Modules	Mounting Structures and Trackers	Cables and Combiner Boxes	Inverters	Balance of Plant: Electrical	Balance of Plant: Civil	End of Life Management
Lamination	Steel profiles	AD/DC cables	Centralised inverters	DC and AC network (cables)	Installation, logistics, construction	Recycling of panels
Junction Box	Aluminium profiles	Conductors (copper, aluminium rods)	Magnetics	Surge protection devices	Access roads and gates	Reuse (panels, structures, inverters)
Aluminium Frames	Tracker communicati on boxes	Insulation (polymers)	Enclosures	Switchgear	Miscellaneous site civils (drainage, field prep)	Recycling of steel structures and electrical components
Super-Substrate (glass)	Brackets and clamps	Armour (steel)	Transformers	Charge controllers and monitoring systems (excl. semi-conductors)	O&M buildings	
Copper wiring		Combiner boxes	Circuit boards	Conduits and fittings		
Backing Sheet		DC cables connectors	Power stage and electronics	MV/HV transformer		
Ethylene Vinyl Acetate		Normal cables	String Inverters	Earthing grid		
Silicon				Control room		
Poly/ monosilicon						
Ingots and Wafers						
Cells						

Source: Authors' analysis, based on SAREM (2023) and SAPVIA (2022).

Moderate support measures and capabilities development required
Intermediate support measures and capability development required
Intensive support measures and capability development required.

The following sub-sections elaborate on the state of major solar PV subsystem manufacturing in South Africa and the potential for deepening localization.

2.4. Major solar PV sub-systems and potential for localization

2.4.1. Photovoltaic panels and modules value chain

South Africa has established a limited foothold in the core solar PV sub-system, namely in the assembly of solar PV modules based on imported panels. The South African PV module market was estimated at ZAR4.1bn (or US$278m) in 2021 but has almost certainly increased in line with the rapid rise in imports over 2022 and H1 2023. These PV module assemblers employed between 50 and 100 people in 2021.[57]

There are two main solar PV module assemblers: Seraphim and ARTsolar that collectively have the capacity to assemble 600MW/pa. However, it is uncertain if they are operating at full capacity, and neither is tooled up to assemble the most up-to-date panels. Rather than being sold in the South African market, some older generation panels assembled locally have been exported to neighbouring countries.[58] Large scale PV projects prefer high-power modules, typically 500W-600W. ARTSolar can provide 500 to 550W, while Seraphim can provide AC Direct 560W and SolarDirect 550W.[59] Seraphim previously announced plans to expand production and two other companies have expressed their intent to establish significant module assembly: African Quartz Photovoltaics and Ener-G-Africa.[60] However, it is unclear how far these investment plans have progressed. Trade policy uncertainty with respect to modules has been evident. An application for a 10 percent import duty on imported panels was initiated in April 2019 but has not yet been concluded.

There is no upstream integration in the South African market in production of solar PV panels which runs from the processing of silica into polysilicon, ingots, wafers, cells, and panels.

There appear to be two main routes to raising local content in relation to solar PV modules. The first, and easier route is through limited forward integration to increase the level of componentry associated with the assembly of modules. This includes localization of processes and componentry related to panel assembly including lamination, junction boxes and aluminium frames. More challenging given local capacity and costs would be the localization of super-substrate (glass), copper wiring, backing sheets and ethylene vinyl acetate.

The second, far more challenging but highly value adding opportunity would be to process South African silica deposits into polysilicon. The feasibility of doing so requires exploration with potential technology partners. Particularly desirable would be if feasible conditions could be established to produce green polysilicon using renewable energy. Drivers for such a scenario include the EU's desire for more diversified and sustainable supply chains, South Africa's silica deposits and abundant solar and wind resources and the advantage green polysilicon and its derivative products enjoy with respect to European CBAM taxes. As polysilicon comprises around 25 percent of the cost of a solar panel [61]the establishment of 'green polysilicon' could pave the way for the further development greener production of the ingots, wafers, and cell parts of the value chain. An alternative scenario could be the attraction of Chinese investment in polysilicon as part

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[57] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

[58] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

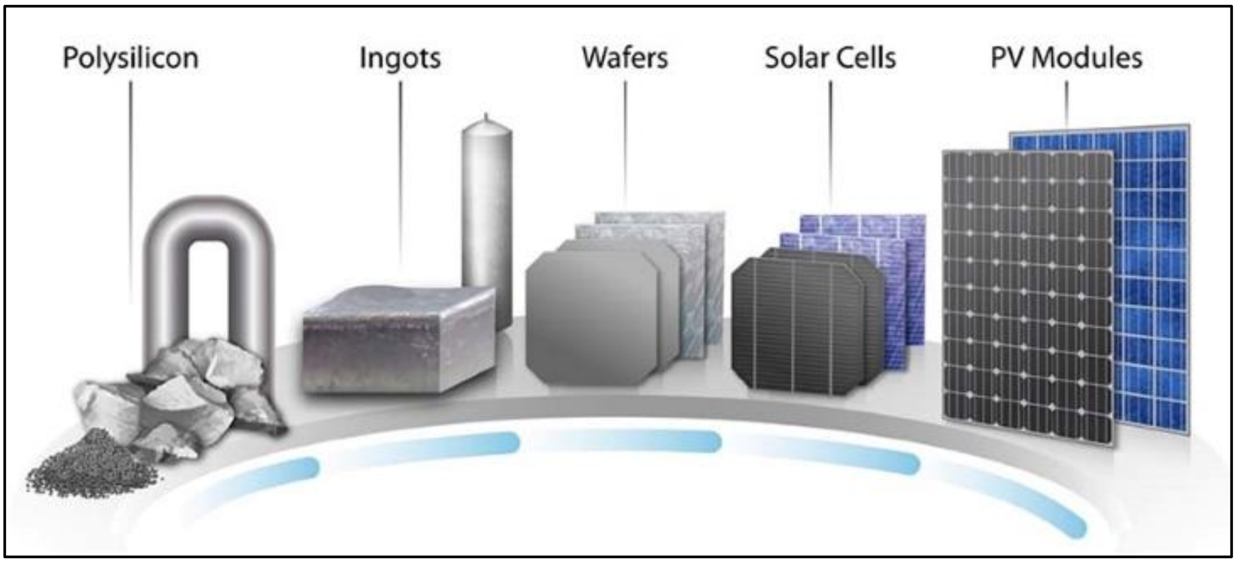
[59] https://serafim-solar.com ; https://artsolar.net

[60] http://www.thedtic.gov.za/ener-g-africas-r135m-investment-transforms-south-africas-energy-landscape/

[61] Green Rhino Energy (n.d.) Value Chain Activity: Producing Polysilicon. Polysilicon | Solar Value Chain (greenrhinoenergy.com)

of an emerging pattern of outward investments to mitigate potential risks to access to EU and US markets (Figure 6).

Figure 6: Polysilicon Value Chain



Source: National Renewable Energy Laboratory (2021)[62]

2.4.2.Mounting structures and trackers

SAPVIA estimates the 2021 mounting structure and tracker market at ZAR820m, employing 750 – 900 people, making it the highest employment sub-system in the South African solar PV manufacturing eco-system. Domestically manufactured trackers capture over 30 percent of the local market, while racks have a 15 percent market share[63] This sub-sector is arguably the most developed solar PV subsystem in South Africa and exports to the rest of the continent.

Domestic manufacturers listed by SAPVIA include STI Norland, KD Solar, Axe Struct, Lumax Energy, Valsa Trading, IMAB Technologies and Rubicon. GreenCape also records SolarFrame and Caracal Engineering.[64] Local content is high at 90 percent or above. Subcomponents including anchors, IPE profiles, brackets, torque tubes, arms set and drive rods, are locally manufactured. Aluminium extruders Hulamin and Wispeco both supply the mounting and tracker market with aluminium extrusion parts and fasteners.

The most significant material costs are steel and aluminium profiles, both of which are priced at import-parity levels. Hence mounting and tracking structure manufacturers derive no pricing benefit from domestic metals suppliers.[65] The sub-sector also requires further investment by local aluminium extruders to expand their own production and to meet stringent product specification and warranty conditions.[66]

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[62] NREL (n.d.). Solar technology cost analysis [Solar Technology Cost Analysis | Solar Market Research and Analysis | NREL]
[63] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.
[64] GreenCape supplier database (2021) cited in Rivett-Carnac (2022).
[65] Rivett-Carnac, *Insights into the Solar Photovoltaic Manufacturing Value Chain in South Africa*.
[66] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

There is significant potential to scale up domestic production of mounting and tracking structures, both for the South African market and the rest of the continent and potentially the EU.

2.4.3.Inverters

The 2021 inverter market was estimated at ZAR980 million, employing between 190 and 210 staff. As with panels, the market size is likely to have increased on the back of dramatic increases in imports during 2022 and H1 2023. There are four local assemblers of inverters: ArioGenix and RWW (producing large grid-tied Inverters) and Engineering, Microcare, and MLT (focused on micro-grid inverters). Locally produced inverters supply less than 10 percent of South African market demand, meaning over 90 percent is imported.[67]

South Africa appears to be more competitive in the production of inverters for residential and small scale commercial and industrial applications, but less competitive in producing inverters for utility scale applications. South African manufacturers appear to be particularly competitive with premium quality off-grid inverters relative to US and European competitors. While MLT and Microcare developed the capacity to produce grid-tied inverters they discontinued these products due to the costs of complying with European Union (EU) electromagnetic interference standards. This is notwithstanding the market gap created when some international inverter OEM's: AEG Power Solutions and SMA Solar closed their South African operations due to REI4P delays.[68]

Italian inverter manufacturer Enertronica Santerno established facilities to repair their imported inverters sold in South Africa, in 2021. In October 2022 it also announced its intent to invest €1 million in local production of inverter and storage capacity.[69]

While South Africa imports a considerable proportion of both string and centralised inverters there is scope to attract investment. This includes exploring whether the two European major global inverter manufacturers that invested in manufacturing facilities in South Africa, but closed due to REI4P rollout delays, could be attracted back into the South African market, and whether or not there would be interest from EU manufacturers to position in South Africa.

2.4.4.Cables

SAPVIA estimates the 2021 cable market at ZAR350 million, with domestic manufacturers supply less than 10 percent of local demand with local content levels of 30 percent and employing between 400 – 450 people. Domestic industry is competitive with larger gauge DC (collector) and AC cables, supported by local content designations. It is less competitive against imports of smaller flexible PVC cables used in combiner boxes. Cables are constructed of copper or aluminium wire surrounded by weather resistant polymers. Only copper cables are manufactured in South Africa.[70]

Aberdare Cables, Alvern Cables, South Ocean Holdings Limited, and Walro Flex manufactured solar PV cables domestically. Phalaborwa Mining Company (PMC) is the sole producer of primary copper in South Africa and is undergoing an upgrade to extend the life of mine, while copper scrap

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[67] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.
[68] Rivett-Carnac, *Insights into the Solar Photovoltaic Manufacturing Value Chain in South Africa*.
[69] https://www.engineeringnews.co.za/article/italian-energy-education-footprint-expands-in-south-africa-through-dedicated-lab-2022-10-17
[70] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

is also an important source of demand. Copper cable theft and illegal export has become an endemic problem as international copper prices have soared. The effectiveness of measures to prevent copper cable theft and prevent illegal exports will be an important determinant of the price at which recycled copper is available on the domestic market.

2.4.5 Electrical balance of plant: charge controllers, solar breakers, combiner boxes, switchgears, and transformers

SAPVIA estimates the market for charge controllers, combiner boxes and switchgears supplying the solar PV market in 2021 at ZAR610m, supplying between 15 percent and 30 percent of domestic market demand, and employing between 800 and 920 workers.[71]

DC combiner boxes combine DC inputs to an inverter and come in various sizes and serve multiple market segments including residential, commercial and industrial, agricultural, mining and utility-scale applications. A trade policy anomaly is evident in that combiner box assemblers pay a 20 percent import duty on some electrical subcomponents such as PC boards and fuses. A technological shift from centralized to string inverters for large-scale PV application is a threat to the industry. There are three main local combiner box manufacturers in South Africa: HellermannTyton, Weidmuller and Allbro. The former two are international companies with manufacturing facilities in South Africa while Allbro is a domestic firm. They also produce other solar PV related sub-components including conduits and fittings, cable ties and clips, tracker communication boxes, junction boxes and transformer bushings[72]. While imported combiner boxes enter South Africa duty free, some components required to assemble combiner boxes, such as PC boards and fuses face an import duty of 20 percent.[73]

Two South African local switchgear manufacturers are manufactured under licence in South Africa: RWW Engineering and Switchgear Unlimited. Both export under licence elsewhere on the continent including Ghana, Guinea, Sierra Leone, and Mali as well as to countries in Southern Africa, including Zimbabwe, Botswana, the Democratic Republic of Congo, Mozambique, and Zambia.

Solar charge controllers (or regulators) and associated solar monitoring systems are produced by local inverter manufacturers Microcare and MLT. Microcare and Rubicon also produce solar geyser controllers compatible with PV systems.

Locally produced transformers supply up to 40 percent of the market, employing between 500 and 600 people. Although transformers imported from India are around 20 percent cheaper than locally produced one's domestic products are of superior quality. Transformers for the solar PV market are not a high share of local producer sales, though – of the order of 10 percent. Local producers include SGB Smit, Armcoil Afrika, Actom, Reliable, Revive, Free State Transformers, Zest Weg, Transformer Manufacturers and Eloff. The expansion of transformer manufacturing for the domestic and export solar PV market may be a promising opportunity given that quality is reported to be as good or better than Asian and European products, manufacturers are compliant

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[71] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

[72] South Africa primarily imports solar PV components, including conduits and fittings, cable ties and clips, tracker communication boxes, junction boxes, and transformer bushings. During the first half of 2023, South Africa quadrupled its imports of solar panels from China to 3.4 GW.[CapeTownEtc (2023). South Africa's solar panel imports from China skyrocket in first half of 2023. South Africa's solar panel imports from China skyrocket in first half of 2023 (capetownetc.com)

[73] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

with international ISO and IEC, and local South African National Standards (SANS) and manufacturers have local testing capabilities.

2.5. Standards and Testing

The South African standards system is a critical framework that governs the development and maintenance of standards within South Africa. The South African Bureau of Standards (SABS) is the primary standards development organization in South Africa. It operates under the South African National Standards (SANS) brand. SABS is responsible for developing, promoting, and maintaining national standards. The organisation collaborates with other organisations and international bodies to ensure that South African standards align with global best practices. The standards system operates within a regulatory framework designed to ensure the adoption and compliance of standards. This framework includes legislation such as the Standards Act of 2008, which empowers SABS to develop and publish national standards.

National standards as per SANS are central to the system. These standards are developed through a rigorous process and are periodically reviewed and updated to reflect technological advancements. From an international perspective, South Africa participates in international standardization efforts through bodies like the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) in order to harmonise with international norms facilitating trade.

Conformity assessment bodies verify compliance with South African standards. They provide certification and testing services to ensure that products, systems, and services meet the relevant standards. The National Regulator for Compulsory Specifications (NRCS) oversees this aspect. The NRCS declares certain SABS standards as mandatory.

From a testing perspective, The South African National Accreditation System (SANAS) is responsible for accrediting testing facilities. Accreditation by SANAS is required for testing laboratories, inspection bodies, and calibration services to demonstrate their competence and impartiality. It operates under the South African Accreditation Act of 1997 and the Accreditation for Conformity Assessment, Calibration, and Good Laboratory Practice Act of 2006. Facilities must demonstrate compliance with international standards, such as ISO/IEC 17025 for testing laboratories. SANAS is a signatory to international agreements such as the International Laboratory Accreditation Cooperation) (ILAC) and the (the European co-operation for Accreditation (EA) which means that SANAS-accredited facilities' test results are widely accepted.

The National Metrology Institute of South Africa (NMISA) is part of the Department of Trade and Industry’s (the dtic) family of technical Infrastructure Institutes, which is responsible for the measurement standards and sciences, procedures and regulations for goods and products. The institution is responsible for maintaining the national measurement standards in South Africa and ensuring their traceability to international standards. The NMISA has developed some accurate measurement for green energy and environmental compliance with a specific focus on renewable energy, energy efficiency, responsible natural resource exploitation, and environmental protection. This makes up the foundation for the development and calibration of testing services and facilities based on international measurements and standards.

One of the leading test facilities for solar PV in South Africa is operated by the Council for Scientific and Industrial Research (CSIR). The CSIR solar PV module testing laboratory in Pretoria provides the equipment, expertise, and capacity to undertake accelerated reliability stress testing on PV modules to ensure their quality and reliability. The laboratory is accredited by SANAS-and can undertake 16 testing methods. The lab currently conducts testing for modules originating from local and international locations and has the capacity to test crystalline, thin film, high capacitance, and bifacial modules. It offers *inter alia*, accelerated stress tests, environmental and mechanical stress testing, humidity freeze testing, damp heat testing, mechanical load testing: static and dynamic load for simulating transportation, installation, and wind loads; sun simulator testing, high potential electrical testing, module -level performance testing, soiling studies, degradation studies and small-scale strong inverter system testing in a real-world environment. Labs at other South African tertiary institutions conducting tests in accordance with IEC 62446-1 include Nelson Mandela University in Gqeberha in the Eastern Cape.

Comments from interviews undertaken for this study suggested that South Africa's standards and testing systems do not fully conform to expected EU requirements. The testing of solar PV modules and South African testing capabilities and certifications for modules to comply with IEC 61215 in the South African SANS 61215 was raised as needing attention. Comparison between the local demand for modules and the capacity of the various laboratories to test imported modules and/or modules for export was beyond the scope of this study.

A summary of the main standards and tests is shown in figures 7 and 8 and an indication of the extent to which South African manufacturers are meeting the standards that their international counterparts are meeting. Additionally, off takers may have specific requirements and/or specific combinations of requirements that manufacturers may insist upon. In Figure **7** it is observable that South African facilities do not provide the same testing as the international manufacturers shown.

Figure 7- Certifications and Standards- PV modules. South African and international comparison

Certification/Standards requirement	International OEM examples					RSA Assembly/Lamination Facility	
	Jinko Solar	Trina Solar	JA Solar	LONGI	Canadian Solar	Other local manufacturer	Seraphim
IEC 61215: Requirements for the **design qualification** of terrestrial PV modules	✓	✓	✓	✓	✓	✓ but for old manufacturing equip. & module tech w/ smaller cell sizes	✓ but for smaller cell sizes
IEC 61730: Construction requirements for PV modules to provide for **safe electrical & mechanical operation**	✓	✓	✓	✓	✓		
IEC 62108: Minimum requirements for the design qualification and type approval of concentrator PV modules and assemblies as defined in IEC 60721-2-1	✓						✓ but for smaller cell sizes
IEC 62941: Applicable to organizations that **manufacture PV modules** certified to IEC 61215 series and IEC 62108 for design qualification and type approval and IEC 61730 for safety qualification.	✓	✓	✓	✓			✓ but for int'l mfgr facility only
ISO 9001: International standard, that sets out the **criteria for a quality management** system.	✓	✓	✓	✓	✓	✓	✓
ISO 61000-6: An **electromagnetic compatibility** standard developed to keep interference between electronic devices under control to reduce disturbance in residential and C&I environments.	✓	✓			✓	✓	
IEC 61345: Standard defines a **UV radiation test** to determine the resistance of a module to UV rays	✓						
IEC 62804-1-1: Defines procedures to test for potential-induced **degradation-delamination** mode in the laminate of crystalline silicon PV modules-principally those with one or two glass faces.	✓	✓		✓	✓		✓
IEC 62716: Standard describes **ammonia tests sequences** that are used to determine the resistance of PV modules to ammonia.	✓	✓	✓	✓	✓	✓	✓

Source: SAPVIA, 2022

Inverters are the most common causes of plant problems and therefore require stringent certification as Figure 8 indicates. Again, South African manufacturers of inverters do not meet the same standards as their international counterparts, notably the minimum requirement for NRS 097-2.

Figure 8: Certifications and Standards- inverters. South African and international comparison

Certification/Standards requirement	International OEM examples			RSA Manufacturer	
	Sunsynk	Kodak	Growatt	MLT/APEX	Microcare
The NRS 097-2: Specifies **minimum technical requirements for low voltage grid connected generators**, in accordance with requirements of the grid code for renewable power plants	✓	✓	✓		
IEC 62109: Applies to the **power conversion equipment for use in PV systems** where a uniform technical level with respect to safety is required		✓	✓	✓	
IEC 61727: Standard applies to utility-interconnected PV power systems operation in parallel with the utility and using **static non-islanding inverters** for the conversion of DC to AC.	✓				
IEC 62116: Standard provides a **islanding prevention testing method** to evaluate the performance of islanding measures used with utility-interconnected PV systems.			✓		
UL 1741: **Test standard** is for certifying products which meet the rigorous requirements needed to ensure safe and reliable operation in support of grid modernization efforts.	✓		✓		
IEEE 1547: Standard sets out criteria & requirements for **interconnection of distributed energy resources** with electric power systems, and associated interfaces.	✓		✓		
VDE-AR N 4105:2018-11: This international standard compiles the **technical requirements** for the connection of generation and storage units to the low voltage network	✓	✓	✓		
DIN VDE V 0124-100: This international standard serves to verify the electrical properties of generation units in accordance with VDE-AR N 4105:2018-11	✓	✓	✓		
ISO 9001: This international standard sets out the criteria for a quality management system.	✓	✓	✓		✓

Source: SAPVIA, 2022

For C I & M most commercial banks specify Tier 1 certification for key solar PV project equipment due to the lower perceived risk profile. A typical solar PV module performance warranty is 20–25-years. In essence off takers require testing to be undertaken which is not currently the norm in South Africa. Should South Africa wish to export modules or ensure that imported and local inverters are performance guaranteed, there are limited facilities to undertake the tests and provide the certification and accreditation required. This represents an opportunity for the future in the solar PV value chain as demand continues to increase either to partner with EU testing facilities to expand their range within existing facilities in South Africa, or to build more testing facilities or both.

2.6. End of Life

Solar PV modules can be recycled at the end of life (EoL) using different methods. Waste from end-of-life solar panels presents opportunities to recover valuable materials and create jobs through recycling. According to IRENA, by 2030, the cumulative value of recoverable raw materials from end-of-life panels globally will be about US$450 million, which is equivalent to the cost of raw materials currently needed to produce about 60 million new panels. Diverting solar panels from landfills to recycling saves space in landfills in addition to capturing the value of the raw materials. Glass represents most of the weight, and glass recycling is a well-established industry.

Other materials that are recyclable include the aluminium frame, copper wire, and plastic junction box. Inverters, racking, and battery backup systems may also be recycled. Inverters may be able to be recycled with electronic waste, and racking may be recycled with similar scrap metals.[74] Battery-based grid energy storage systems may be handled with current battery recycling programs.[75] Recycling involves separation of the glass and silicon wafer initially by thermal,

[74] MIT Technology Review (2023), Solar panels are a pain to recycle. These companies are trying to fix that. Solar panels are a pain to recycle. These companies are trying to fix that. | MIT Technology Review

[75] Environmental Protection Agency (EPA (2023). Solar Panel Recycling | US EPA

mechanical, or chemical means, then the removal of the frame and junction box, and finally the separation and purification of silicon cells and specialty metals (e.g., silver, tin, lead, copper) through chemical and electrical techniques. Recycling is already established for metals, glass, and electronics, in South Africa and solar PV modules can make use of this or proceed alone-investment will be cost recovery dependent. Currently, about 90 percent of end-of-life or defective solar panels end up in landfills because it is less costly than recycling. However, recycling is becoming more cost-effective, and landfilling costs are increasing, so the gap between the two is expected to begin to close.[76]

In 2016, the IRENA and the International Agency for Photovoltaic Power Systems (IAPPS) predicted that South Africa could accumulate between 750 000 and one million tons of photovoltaic waste by 2050.[77] Given the exponential growth of demand for solar PV, the recycling of Solar PV waste will shortly become relevant and represents an opportunity. Under the Extended Producer Responsibility (EPR) Regulations, which came into effect in May 2021, solar panel producers and importers must take responsibility to ensure that much of their products are returned (and recycled by an accredited and licenced facility) after being sold and used. Manufacturers, importers, and brand owners are held accountable for the entire life cycle of the products they place on the market, from conception to post-consumer waste disposal. Additionally, the implementation of the amendment to the South African National Environmental Management: Waste Act (No. 59 of 2008) banned all waste electronic and electrical equipment from landfill as of August 2021.

Current challenges to be addressed for EoL management of solar PV modules and components include the fact that most current recycling plants are unequipped to deal with them. The recycling processes involved generate large amounts of glass containing toxic dust (lead, silicon, cadmium etc) and harmful gases such as nitrogen oxide are emitted in the process. Recycling consumes high amounts of energy and finally the recycling process currently costs more than the potential value of the recycled end products.[78]

There are no data available for South Africa, but in the US, recycling a solar panel can cost US$15-45, while sending a panel to the landfill costs only US$1-5.79. In the EU, legislation requires PV manufacturers to recycle waste panels and recover at least 80 percent of their mass.[80] If more materials could be recovered at a higher purity, they would have a greater market value and make recycling more economically attractive. Currently PV Cycle, Veolia, and SolarCycle are some of the waste companies in the EU that process solar PV panel waste and have several plants in the EU, as well as in the US.

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[76] Yale Environment 360 (n.d.) As Millions of Solar Panels Age Out, Recyclers Hope to Cash in. As Millions of Solar Panels Age Out, Recyclers Hope to Cash In - Yale E360

[77] Prinsloo, I. (2023). South Africa's solar power boom should include plans for environmentally sound waste management. South Africa's solar power boom should include plans for environmentally sound waste management - Circular Energy (circular-energy.org)

[78] Pretorius, F. (2023). South Africa not ready to recycle solar panels. Institute for Futures Research, Stellenbosch University.

[79] US National Renewable Energy Laboratory (NREL) (2022). Solar panels face recycling challenge. European Community Directive, numbered 2012/19/EU,

[80] European Waste Electrical and Electronic Equipment Directive (WEEE)

2.7. Gender Equality and Social Inclusion

Gender Equality and Social Inclusion in a changing world is a social justice and economic imperative, especially in South Africa where poverty is gendered and racialised. The incidence of poverty is particularly high for black women at 57 percent. Unemployment rates are higher for women than for men at all ages. Women's realities in South Africa are still determined by races, class, and gender-based access to resources and opportunities. When women are employed, this typically remains within the traditional female occupations or within the domestic and farming sectors- concentrated in positions which do not pay well, and which have high turnover rates. The cultural view of women's caring responsibilities means that women provide on average, more than twice the time of men to household and family care work (elderly and children) and they make up 97 percent of caregivers qualifying for the Child Support Grant. [81] the Just Energy Transition (JET) in South Africa requires that women, especially black women are included in all areas of the RE value chains, including Solar PV and there are clear opportunities for increased inclusion of women and youth in certain occupations and at certain stages along the solar PV value chain, discussed below.

The EU has taken several steps to include women in the solar PV value chain. It has introduced policies to accelerate the deployment of rooftop solar by addressing general challenges faced by the sector, such as high costs and a lack of appropriate financing and has encouraged policymakers to create gender-targeted policies to enable companies to advance towards gender parity and ensure that the sector's growth will be gender-inclusive. Currently, women account for 40 percent of the EU solar PV workforce, which is almost double the share of women employed in the wind industry (21 percent) and the oil and gas sector (22 percent). Women are more included however, in solar PV manufacturing, representing 47 percent of the workforce, service providers and developers follow with 39 percent and 37 percent. Numbers are low in solar PV installation at 12 percent of the workforce. Decentralized solar PV can offer significant opportunities for women, especially rural women as the off-grid solar PV value chain engages women both in delivering solutions and as beneficiaries.[82]

South Africa's greatest inclusion challenge is to address unemployment and poverty. The SAPVIA report estimates that approximately 20,000 people are currently employed in the solar PV industry (on a full-time equivalent basis), overwhelmingly in the construction and installation parts of the value chain, and approximately 3,000 in domestic manufacturing and 3,000 in project development. As discussed above employment intensity within solar PV manufacturing also varies significantly from 50-100 employed in module assembly to 750-900 in mounting structures and trackers and 800-920 in electrical BoP. Based on the World Bank's estimate of a substantial indirect job multiplier of 3.8 jobs created for every manufacturing job created, this suggests that the 3,000 solar PV manufacturing jobs have created or support 11,400 jobs elsewhere in the economy: a total of 14,400 jobs. With the explosion of commercial, industrial, and residential SSEG rooftop solar installations since early 2022 the estimate of 20,000 Full Time Equivalent (FTE) jobs created at the installation stage is likely to a considerable under-estimate. However, no specific data appears to be available to estimate the employment impact of these smaller scale installations. Similarly, the potential employment impact of a nascent EoL and recycling industry remains to be quantified. Both are important areas for further research.

South Africa's policy stance regarding GESI in the implementation of RE programs and projects reflects a commitment to fostering equity and inclusivity in the transition to sustainable energy

[81] OECD (n.d.) Patterns of gender inequality persist in paid workforce and entrepreneurship.
[82] IRENA (2022). Solar PV: A Gender Perspective.

sources. The South African government recognizes that GESI considerations are integral to the success and fairness of RE initiatives and the Just Transition (JT). South Africa has adopted a multifaceted approach, emphasizing the importance of women's participation and empowerment in the RE sector. This approach includes promoting women's representation in decision-making processes, facilitating access to funding and training for women entrepreneurs in the renewable energy sector. These include the EC JETP, USAID, the International Partners Group (IPG), and the United Nations Development Programme (UNDP). The UNDP regional service centre for Africa for example, held the first regional Training of Trainers on the Gender Equity Seal for Public Institutions in Africa, involving regional representative including South Africa. By integrating GESI principles into its RE policies, South Africa aims to ensure that the benefits of the clean energy transition are shared equitably among all segments of its diverse population. [83]

An important report in this regard is the SAPVIA, Department of Mineral Resources and Energy (DMRE), SAWEA and GIZ report of 2022. A summary of the current state of gender diversity in the utility scale and solar wind energy sectors in South Africa was provided along with recommendations to improve gender diversity in the sectors. The study noted that 19 percent of directors in the wind and solar power energy sectors were women (at the time of the study), and 80 percent were men, while 33 percent of all employees across both sectors were women. Several critical barriers to entry and career progression were identified for women and high-level recommendations for improving inclusivity for women and non-binary people were made.[84]

GESI mainstreaming across all South African projects and programmes in the solar PV industry will require specific action to be taken along the value chain but also in terms of the local skills supply chain into the industry. Commercial entry points along the value chain include all value chain points, however, this does not address the issue of access to Solar Power by vulnerable groups, especially in the rural areas. GESI does not mean only participation in commercial opportunity along the value chain, an equally critical element will be using solar PV to address energy poverty. While many formal businesses and relatively well-off households can finance solar PV, poor households and survivalist businesses typically cannot and in some rural areas there is no access to Eskom electricity. A specific option for considering off grid solar PV as part of Community Social Upliftment in the Broad-Based Black Economic Empowerment (B-BBEE) context could be considered.

In terms of REI4P however, the inclusion of women in IPP projects has been targeted at only five percent.[85] Of a total procurement spend of ZAR99.4 billion, only ZAR4.2 billion was procured from women owned enterprises- amounting to six percent. No data are available for youth owned enterprises. Total procurement from black owned enterprises was 83 percent of ZAR99,4 billion. There is a clear need for significant improvement in women inclusion in the REI4P and in RE overall.[86]

Several programmes exist within the Development Finance Institutions (DFIs) of the dtic (National Empowerment Fund [NEF] and the IDC) as well as within the Department of Women, Youth and Persons with Disabilities (DWYPD) focusing on the empowerment and inclusion of women,

[83] IRENA (2019); Adendorf et al (2020)
[84] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH (2022). Study on Gender Diversity in the Wind and Solar Energy Industries in South Africa.
https://www.energypartnership.org.za/fileadmin/user_upload/southafrica/media_elements/Study_on_Gender_Diversity_in_the_Wind_and_Solar_Energy_Industries_in_South_Africa_Final.pdf
[85] IPP Office (2020). Independent Power Producers Procurement Programme (IPPPP)An Overview.
[86] Independent power producers' procurement programme (IPPPP) (2023)

especially black women. Many Non-Government Organisations (NGOs) such as Harambee[87] run specific programmes and there is a quota for black women contained in the South Africa B-BBEE programme, albeit low. This is consistent with working towards promoting gender diversity and inclusion in the RE sector. For example, the Isivande Women's Fund aims to enhance socio-economic development in rural, peri-urban and township areas by empowering South African women, especially black women, through financial assistance and non-financial support, some of which focuses on RE and solar PV. There are limited gender specific data on support made available to women for participation. In solar PV by the leading DFIs, however a recent study of DFI performance in terms of allocating industrial finance indicated that overall, the various DFIs should increase their allocation to women owned enterprises.88 Inserting the solar PV strategy for GESI and setting targets for inclusion will assist women to access more funding and support increased allocations for women.

working towards promoting gender diversity and inclusion in the renewable energy sector. For example, the Isivande Women's Fund aims to enhance socio-economic development in rural, peri-urban, and township areas by empowering South African women, especially black women, through financial assistance and non-financial support some of which is in RE and some in Solar PV. There are limited gender specific data on the support made available to women for participation in Solar PV by the leading DFI's, however a recent study of DFI performance in terms of allocating industrial finance indicated that overall, the various DFIs could increase their allocations to women owned enterprises.89 inserting the Solar PV strategy for GESI into the DFIs and GESI programmes, and setting targets for inclusion, will assist to increase funding and support allocations to women. Additionally, the Black Industrialist (BI) programme seeks to support and include black women and men in the industrial sector.

There are a number of high profile and successful programmes for the training and inclusion of black youth. One example is the Presidential Youth Employment Intervention (PYEI) run by the Presidency which shifts young people from learning into economic activity. Specific funds have been set up, some by the private sector, some by government and some in public private partnerships to ensure optimum black youth inclusion and include the Small Enterprise Development Agency (SEDA), the Small and Medium Enterprise (SME) fund, the Jobs Fund, and others.

Currently, based on the literature and document review, and interviews undertaken, the main opportunities for black women and youth are likely to be largely in trade, retail, and installation, maintenance, repair, and recycling with special opportunities for women and youth in rural areas in off grid solar PV. Specific programmes and a GESI strategy are required for the solar PV industry to ensure optimum inclusion.

There may also be potential to roll out solar PV to low-income housing in state social housing projects where the solar PV module is mounted as part of the housing unit and is absorbed into that cost, as most people living in townships and poor rural communities cannot afford the current installed cost of a unit. There are high levels of demand. Approximately 22 million people in South Africa live in townships, excluding many more millions living in rural areas. In Gauteng alone, out of a total of about 5.5 million private dwellings, around 2.7 million were in townships[90] One

[87] The Harambee Youth Employment Accelerator's 6th Solutions Exchange for Youth Employment
[88] the dtic (2022). Access to industrial finance. Unpublished.
[89] the dtic (2022). Access to industrial finance. Unpublished.
[90] Majola, G. (2022). Granville Energy eyes solar opportunities in townships. IOL, Granville Energy eyes solar opportunities in townships (iol.co.za)

additional option is to provide support to municipalities to establish community-owned PV solar systems. This has the potential to decentralise and increase local energy supply.

To give effect to increasing women and female youth participation in the sola PV sector, a number of steps need to be taken. First, the availability of these jobs needs to be communicated to women through outreach communications (via social media and community radio) and potentially for some women, assistance in applying may need to be offered, especially if applications are online. In manufacturing or assembly at scale, the jobs are location bound- if the factory is in a particular area, it will stay there so the jobs are largely accessible to women in the area. Second, women need to be trained and skilled in short solar PV courses that are certified and acceptable to manufacturing, thus the inclusion of women in skills upliftment programmes is critical, (perhaps on a quota system). Thirdly jobs in installation and maintenance are growing faster than any other stage of the value chain so qualifications and access to this work is spread nationally, and in rural areas, where care and maintenance of solar PV systems is critical. Thus, linking skills development and training to all programmes and projects rolling out solar PV regardless of location, will offer access to women and female youth that would otherwise not be as available. Finally, engaging with the DFIs (the NEF, the IDC, SEDA and more) and developing a well monitored inclusion programme with quotas for women owned enterprises and improved access to financial and non-financial support, will assist women owned SMMEs.

3. Benchmarking: international industrial policy support for solar PV

Solar PV (and other renewables) have all been characterised by extensive breadth and depth of demand and supply side measures. Demand: procurement, Feed-In Tariffs (FIT), local content requirements. Supply: Tax breaks, grants, low-cost loans, guarantees, trade measures. Specific advanced economies notably Germany, Korea, Japan, and the United States established an initial technological and industrial leadership in developing and commercialising solar PV technologies.

Three main jurisdictions are currently challenging China's global dominance in solar PV and have or are busy putting in place large-scale industrial policy support measures to do so: the United States, Europe, and India. Both the US and the EU have stated their intention to reduce their reliance on China for strategic inputs required for the green energy transition and digital economy. Türkiye has expressed ambitions to become one of the world's largest solar PV manufacturers.[91] Outside of China and other east Asian economies and the US are only a handful of producers of solar PV modules (used here as a proxy for solar PV manufacturing capacity more generally as indicated in Figure 9). India and Türkiye have both implemented policies aimed at becoming significant players in solar PV manufacturing. India and Türkiye have respectively approximately 28GW[92] and 8.7GW[93] of solar module manufacturing capacity installed compared to South Africa's 0.6GW.[94]

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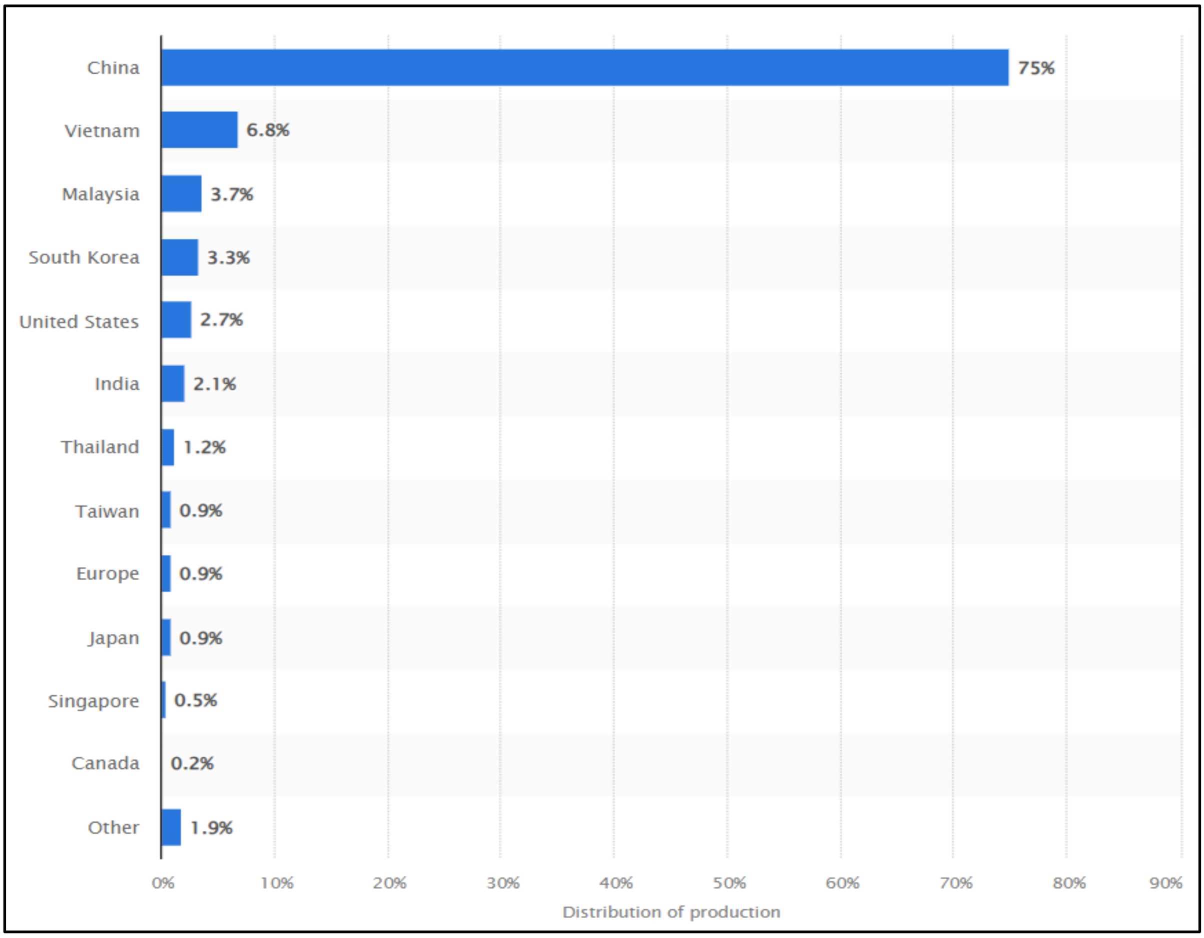
[91] Igor Todorović, "Photovoltaic plant of 1 GW in connection capacity inaugurated in Turkey," *Balkan Green Energy News* 2023, https://balkangreenenergynews.com/photovoltaic-plant-of-1-gw-in-connection-capacity-inaugurated-in-turkey/.
[92] PV Magazine, India (2023). *Indian government says PV module capacity to hit 100 GW by 2026*. Indian government says PV module capacity to hit 100 GW by 2026 – pv magazine International (pv-magazine.com)
[93] Solarbe Global (2022). *Türkiye, a rising star as solar manufacturer*. Türkiye, a rising star as solar manufacturer | Solarbe Global
[94] South African Photovoltaic Industry Association, *The localisation potential of the South African solar photovoltaics (PV) industry and recommendations to support local manufacturing in South Africa*.

Figure 9-Distribution of solar photovoltaic module production worldwide in 2021, by country[95]



Source: Statista, 2023

Policy support programmes of five countries / regions that have emerged as major players in solar PV production and have ambitious programmes in place are thus briefly reviewed.

- China
- US
- EU
- India
- Türkiye

[95] STATISTA (2023). *Distribution of solar photovoltaic module production worldwide in 2021, by country* https://www.statista.com/statistics/668749/regional-distribution-of-solar-pv-module-manufacturing/

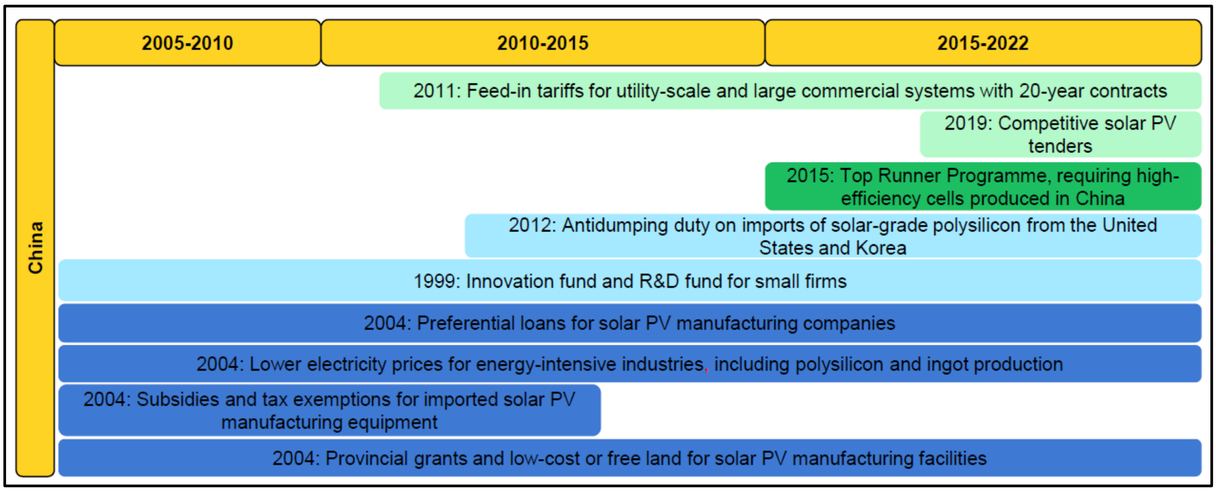
3.1. China

Solar PV has been a priority of China's successive five-year plans since 2001, supported by a range of policy support measures which have been adapted over time. Initially China targeted production for the export market using grants (national and provincial), low-cost loans and innovation funding to establish "pioneer" domestic manufacturers. Grants and tax incentives were used to import solar PV production machinery from Europe and the United States.

Whereas industrial policy initially focused on wafers, cells, and modules, in its second phase policy targeted the domestic production of polysilicon and the capital equipment to produce solar PV components. This included low (coal-based) energy prices as an additional strategic lever, particularly for energy-intensive polysilicon production. In 2019 antidumping duties on imports of polysilicon from the US and South Korea were introduced.

As part of its stimulus response to the 2008 global financial crisis China shifted focus to also promoting the growth of solar PV in its domestic market. Through feed in tariffs (FITs) since 2011 and utility scale auctions in 2019 China has become the world's largest market for solar PV. It has also subsidised demand (through its *Golden Sun* programme) linked to installation of highly efficient technologies including 650kW panels. To promote technological leadership its *Top Runner Programme* provides incentives to manufacturers to target the most efficient technologies, for instance a shift from multi-crystalline to monocrystalline panels. [96] **Error! Reference source not found.** illustrates the range of policies China has put in place to support its solar PV industry between 2005 and 2022.

Figure 10-Supply and demand policies targeting solar PV manufacturing in China, 2005-2022



Source: IEA, 2023

Indirect demand
Direct demand
Indirect supply
Direct supply

[96] International Energy Agency, *Special Report on Solar PV Global Supply Chains*.

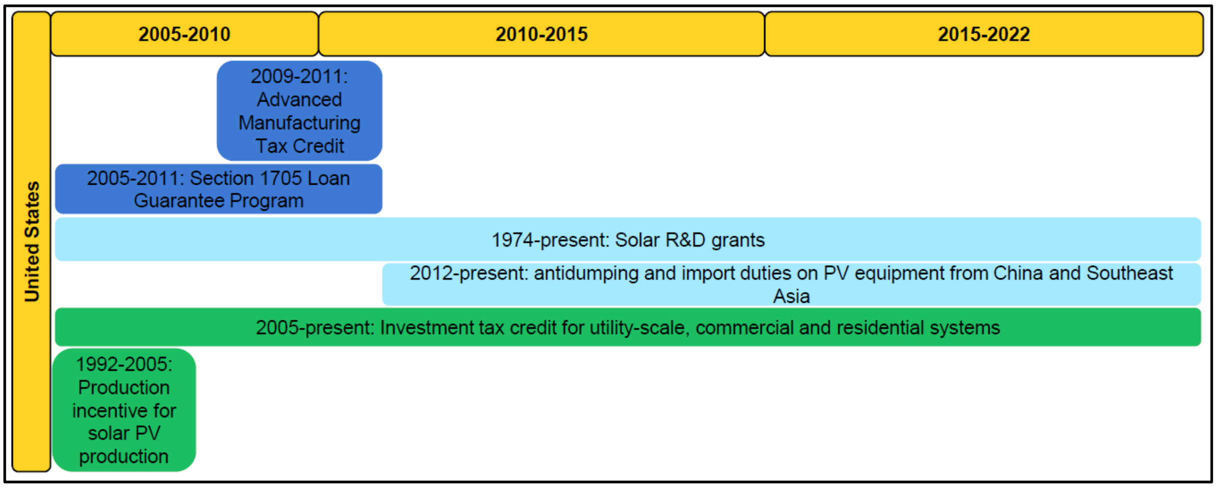
3.2. United States

Like Germany, Japan and South Korea the US government has long supported solar PV research and development through the *Solar Technologies Office* and the *Infrastructure Investment and Jobs Act,* promulgated in 2021. The former has provided grants and loans enabling the US to become the leading producer of thin-film cadmium telluride (CdTe) panels.[97]

Since 1992 the US has also incentivised solar PV demand through a range of measures. Since 2006 these have been in the form of federal tax incentives, which have driven a tenfold increase in demand over the last decade which has supported thin-film manufacturing and module assembly.

Direct support for manufacturing has included loan guarantees and tax credits. An Advanced Energy Manufacturing Tax Credit offered a 30 percent tax credit to establish new, expanded or upgraded facilities. The MTC has raised manufacturing capacity, but supply chain gaps remain. This includes limited polysilicon, wafer, and cell production. Trade restrictions and tariffs have also formed part of the policy mix with antidumping and import duties on Chinese, Malaysian, Thai, and Vietnamese companies in place since 2012.[98] Figure 11 reflects the range of support measures the United States put in place to support its solar PV industry between 2005 and 2022.

Figure 11: Supply and demand policies directly or indirectly targeting solar PV manufacturing in the United States, 2005-2022



Source: IEA (2023)

Indirect demand
Direct demand
Indirect supply
Direct supply

In addition to a long history of substantial support for solar PV, in August 2022 the US enacted the Inflation Reduction Act (IRA). The IRA is a US$370 billion support package for "clean energy, climate mitigation and resilience, agriculture, and conservation-related tax incentives and investment programs" (p6). The IRA provides, inter alia, "stackable" tax credits for investments in solar PV and

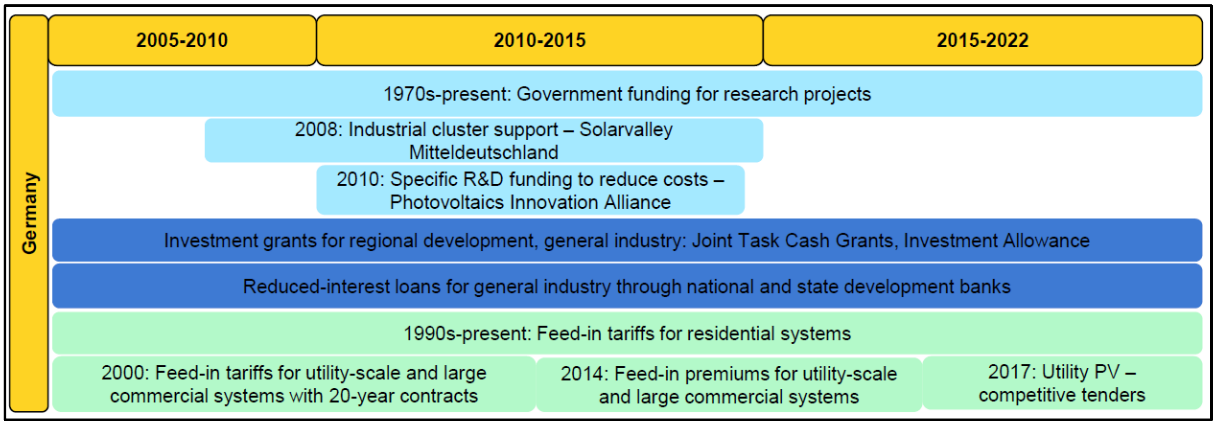
[97] While the US produces 80 percent of thin film cells, it is still a very small part of overall global demand – around 5 percent compared to the crystalline silicon cells and panels made by China.
[98] International Energy Agency, *Special Report on Solar PV Global Supply Chains*.

other renewable electricity technologies. Investments in solar PV and other renewables receive a baseline tax credit of 30 percent of qualifying investment costs, provided it meets decent wage and apprenticeship requirements (if not only 6 percent of the qualifying investment cost is eligible). Additional credit of 10 percent is earned if manufactured inputs into the project meet certain local content requirements. A further 10 percent credit is earned if the project is in an historically coal-dependent "energy community". Thus, up to 50 percent of qualifying investment costs can be incentivized. New solar PV technologies may also benefit from a separate IRA provision of US$40 billion in loan guarantees supporting innovative renewable technologies.[99]

3.3. European Union

Amongst European countries Germany has had the longest record of accomplishment of support programmes for solar PV. By the late 1990s Germany was both the leading European manufacturer and the world's preeminent producer of polysilicon, wafers, cells, modules, and solar PV capital equipment. Since the 1970s Germany has supported solar PV R&D and PV manufacturing through a combination of national and federal grants, tax incentives and concessional loans. This has included its *Joint Task Cash Grants* and *Investment Allowance* programmes. Since the beginning of the 2000s Germany supported solar PV demand through FITs for utility and large commercial projects. In 2008 it introduced a *Solarvalley Mitteldeutschland* industrial cluster support programme targeting medium size companies. In 2010 it introduced funding for R&D to raise production efficiency through its *Photovoltaics Innovation Alliance* programme. Figure 12 reflects the range of policies Germany has put in place between 2005 and 2022 to support its solar PV manufacturing industry. However, since 2011 a wave of cheaper Chinese PV modules has placed significant downward pressure on the market share and profitability of German manufacturers.[100]

Figure 12: Supply and demand policies directly or indirectly targeting solar PV manufacturing in Germany, 2005-2022



Source: IEA (2023)

Indirect demand
Direct demand
Indirect supply
Direct supply

[99] The White House (2022). *Inflation reduction act.* Inflation Reduction Act Guidebook | Clean Energy | The White House
[100] International Energy Agency, *Special Report on Solar PV Global Supply Chains*.

The EU has only recently mobilised a comprehensive framework for solar PV, informed by the strategic objective of greater energy self-sufficiency in the wake of Russia's invasion of Ukraine, a higher level of ambition to tackle climate change, and a desire to diversify away from perceived over-reliance on Chinese supply chains. In 2020 the EU began to set out an increasingly ambitious programme commencing with its *Green Deal* which inter alia targeted a 3-to-5-fold increase in solar PV between 2019 and 2030 of between 325 and 375GW.[101] In May 2022, the European Commission launched its *REPowerEU* policy in the wake of the Russian invasion of Ukraine, with the objective of dramatically reducing the EU's reliance on Russian gas. This includes a *Solar Power Strategy* aimed at further raising the EU's target of installed solar PV by 2030 to 600GW. A major policy measure is the promulgation of regulations that require most new public and commercial buildings to install rooftop solar.[102]

An *EU solar PV Industry Alliance* was launched in December 2022 aimed at scaling EU manufacturing of each major solar component from current levels of 4.5GW to 30GW by 2025.[103]. The alliance will seek to mobilise funding for manufacturing in Europe through various existing programmes.[104] EUR 250 billion is available under the *NextGenerationEU*, via 27 national Recovery and Resilience Facility (RRF) plans, including for industry decarbonisation. *Horizon Europe* offers EUR 40 billion to *Green Deal* related industrial research and innovation. The EU also aims to "facilitate swift mobilisation" of access to EUR 100 billion for solar PV, through facilities such as the Just Transition Fund (JTF*)*.[105]

The European Commission (EC) has also enacted a *Net Zero Industry Act* to support manufacturing of renewable technologies deemed strategic with the objective that the EU develops manufacturing capacity to supply at least 40% of its renewable generations requirements. [106] However, engagements with SolarPower Europe [107] indicate that provisions to limit reliance on a single market to no more than 60 percent are also a potential opportunity for countries like South Africa to supply the EU market.

While welcoming the raft of new policies emphasising the need to revive European solar PV manufacturing and limit reliance on China, some significant concerns have been raised. Chief amongst these is the lack of a single source of dedicated funding that will help European manufacturers overcome high costs of energy and higher wages than China and establish production at the 'giga-factory' magnitude required to compete with the economies of scale Chinese manufacturers have attained. One specific proposal is the establishment of a dedicated *Solar Bank* to provide the funding for such mega-scale investments. [108,109]

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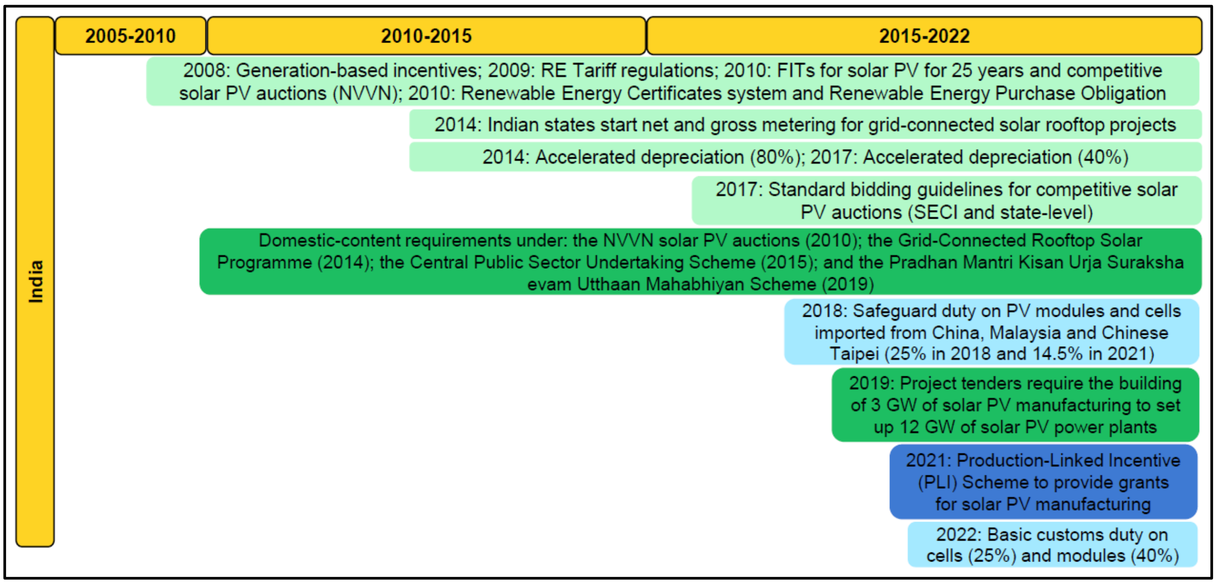
[101] Caravella et al (2023). Technological Sovereignty and Strategic Dependencies: The case of the Photovoltaic Supply Chain, (PDF) Technological Sovereignty and Strategic Dependencies: The case of the Photovoltaic Supply Chain (researchgate.net)
[102] SolarPower Europe (2023). *EU Solar Strategy Explained. A new dawn for European Solar*, EU Solar Strategy Explained - SolarPower Europe
[103] SolarPower Europe, *Global Market Outlook for Solar Power 2023-2027*.
[104] SolarPower Europe, *Global Market Outlook for Solar Power 2023-2027*.
[105] European Commission (2023). *Green Deal Industrial Plan for the Net-Zero Age.* *h*ttps://commission.europa.eu/system/files/2023-02
[106] Financial Times (2023). *Solar power: Europe attempts to get out of China's shadow*. Solar power: Europe attempts to get out of China's shadow (ft.com)
[107] Interview SolarPower Europe, 2023
[108] SolarPower Europe (2023)
[109] Politico (2023). *How will Europe bring back solar manufacturing?* How will Europe bring back solar manufacturing? – POLITICO

3.4. India

India has implemented policies aimed at becoming a significant player in solar PV manufacturing. This has partly rested on leveraging their large internal markets through local content requirements. Since 2008 India introduced a range of policies and incentives to promote the installation of solar PV (Figure 13). In 2010 it included local-content requirements in its public solar auctions. In 2018 it introduced safeguard duties on PV modules and cells from China, Malaysia of 25 percent and 14.5 percent in 2021 from Taiwan. In 2019 project tenders for the installation of 12GW of solar PV required corresponding establishment of 3GW of solar PV manufacturing. In 2021 India introduced a Production-Linked Incentive (PLI) grant subsidy for solar PV manufacturing and in 2022 it introduced 25 percent customs duty on cells and 40 percent on modules.[110]

Figure 13: Supply and demand policies directly or indirectly targeting solar PV manufacturing in India, 2005-2022



Source: IEA (2023)

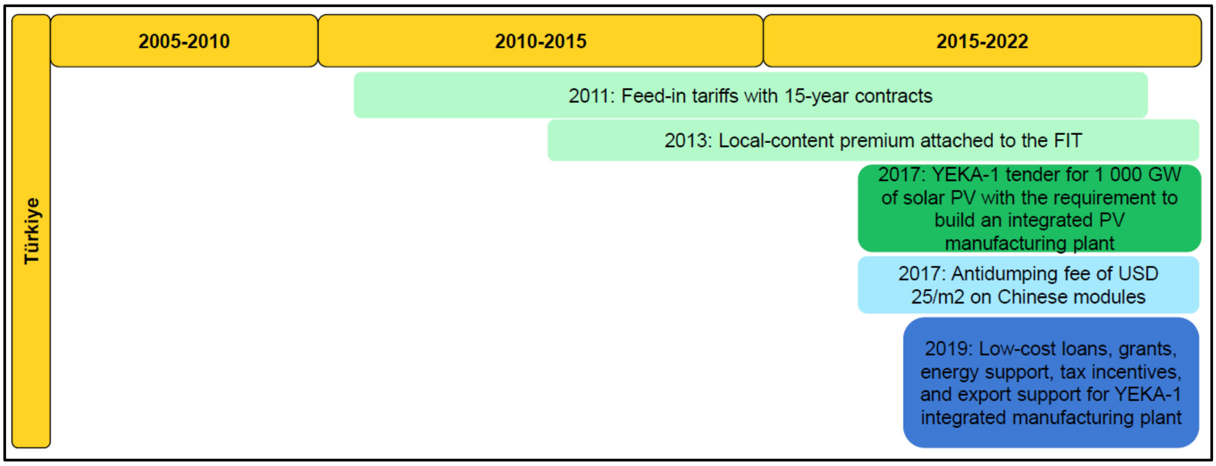
Indirect demand
Direct demand
Indirect supply
Direct supply

[110] Raina, G., Sinha, S. (2019). Outlook on the Indian scenario of solar energy strategies: Policies and challenges, *Energy Strategy Reviews,* 24, Pages 331-341

3.5. Türkiye

In 2011 Türkiye put in place 15-year FITs for the installation of solar PV. In 2013 it implemented a local-content premium as part of its FIT, based on domestic value added (Figure 14). This stimulated domestic assembly of imported Chinese modules. In 2017 it launched a 1GW solar PV integrated plant tender to manufacture all components from wafer to module stage. Estimates of Türkiye's solar PV module manufacturing capacity range between 5.6GW in 2021 to 7.9GW in 2022 and a projected capacity of 9.1GW in 2023. [111] [112]

Figure 14: Supply and demand policies directly or indirectly targeting solar PV manufacturing in Türkiye, 2005-2022



Source: IEA (2023)

Indirect demand
Direct demand
Indirect supply
Direct supply

[111] PV Magazine (2021). *Turkish PV manufacturer report reveals country's annual production capacity is 5,610 MW/year*, [Turkish PV manufacturer report reveals country's annual production capacity is 5,610 MW/year – pv magazine International (pv-magazine.com)]

[112] Hurriyet Daily News (2022). *Türkiye to become one of top solar panel producers:* Minister. [Türkiye to become one of top solar panel producers: Minister - Latest News (hurriyetdailynews.com)]

4. Conclusions and recommendations

4.1. Key findings

Since 2010 there has been a dramatic increase in the deployment of solar PV worldwide. A record 239GW of solar PV was installed in 2022 led by China, followed by the EU, the US and India. Estimates of African solar PV deployment, although small in global terms, indicate significant growth, albeit off a low base. Data cited by IRENA clearly under-estimate the scale of solar PV deployment. IRENA estimates of 1GW installed in South Africa in 2022 are a case in point. SAPVIA estimates that 5.659GW of solar PV had been cumulatively installed by end Q1 2023.[113] Solar PV is now the world's largest source of renewable energy and is set to overtake both coal and natural gas to become the largest source of energy overall by 2027, providing over one fifth of global power capacity.

The solar PV panel and module value chain is the largest sub-system by value of the solar PV value chain and has captured the primary attention of industrial policy makers, including in South Africa. The solar PV value chain also comprises other major sub-systems with potential to expand manufacturing, including mounting and tracking structures; inverters; and manufactured inputs into electrical and civil balance of plant.

China has established itself as both the world's largest installer and manufacturer of solar PV through a combination of massive state subsidisation to drive economies of scale for export, and implementation of the world's large solar PV deployment programme. Chinese companies account for over 80 percent of world market share in panel production and 91 percent of pre-cursor activities involving the conversion of silicon to ingots and wafers required for panels. Chinese economies of scale have driven an exponential reduction in the price of solar PV panels and modules with periods of global overcapacity. Prices of solar panels have fallen from around US$5.00 per watt in 2005 to US$0.38 in 2019.

While a number of countries engage in module assembly based on imported Chinese panels, four main jurisdictions are challenging China's lead in panel production driven by government subsidies and other forms of public support: the US, the EU (particularly Germany), India and Türkiye. On the demand side these include local-content requirements linked to measures to stimulate domestic solar PV demand such as feed-in-tariffs and auctions. On the supply side they include support for R&D, tax credits and allowances, grants, and low-cost financing. Two features of these support regimes are evident. First, where countries have set a high level of solar PV manufacturing ambition, particularly for integrated panel production from polysilicon through to panels and modules, they have put in place a correspondingly substantial level of public support measures. Second, effective support measures have adapted over time as global and domestic industry conditions have changed.

The development of the South African solar PV, and broader renewable market, has until recently been dominated by public utility scale procurement through the REI4P. Localization requirements linked to the REI4P have provided some support for parts of a domestic value chain to emerge across the various solar PV sub-systems. A broad ambition to promote domestic manufacturing

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[113] SAPVIA (2023).

has, however, been undermined by periods of policy uncertainty, and flaws in policy and implementation. One consequence is that several factories that were established to serve REI4P demand closed or have been operating below full capacity.

Since the 2022 baseline report there have been some significant changes in current and anticipated sources of demand and some more limited changes to the structure of the industry[114]. Various policy reforms since 2019 have shifted the source of demand for solar PV from an overwhelming reliance on the public utility scale market to private large scale, C&I, and residential small scale embedded generation projects. While solar PV is likely to remain an important part of the IRP and hence REI4P procurement going forward, private projects will be of a similar or greater magnitude.

South Africa has developed significant, albeit uneven, capabilities across some solar PV sub-systems. This includes assembly of modules; mounting and tracker systems; battery storage (some linked to solar PV); inverters and inputs into electrical balance of plant, particularly cables. Some related and supporting industries are not fully developed, for example, testing facilities and standards development. While South Africa has many of the minerals, materials and metals required for solar PV production across the value chain, these endowments do not automatically translate into sub-system and component production. Rather the most important success factors are acquiring the industrial capabilities to produce these products and attain economies of scale to compete against fierce international competition (invariably enjoying state support) in both the domestic and export markets. Overall, the South African solar PV manufacturing value chain remains fragmented and underdeveloped, albeit with significant opportunities for growth.

While not insignificant, the South African market is not big enough to support substantial growth in solar PV related investment. Thus, international competitiveness needs to be built both to compete more effectively in the domestic market and take advantage of export market opportunities. Competitive participation in the solar PV value chain and its sub-systems requires investment at scale. In the solar panel sub-systems, competitive investments need to be of a 'giga-factory' scale and require continuous reinvestment to adapt to ongoing improvements in panel technologies. While not impossible, the ability of South Africa to compete in upstream production of silicon, ingots, wafers, and panels would require substantial state support as well as knowledge transfer and private capital. However, the South African, Southern African Development Community (SADC) and AfCTA markets along with cheap RE may offer an incentive for investment as this promises greater demand and sales opportunities.

There are clear implications for direct and indirect employment creation. Activities along the solar PV value chain differ with respect to their direct employment creation potential. The most employment intensive part of the value chain is at the installation phase, particularly in the SSEG segment. It is also the segment that appears to be most promising with respect to promoting participation of small, black, women and youth owned companies. Certain sub-system products are also relatively employment intensive including the assembly of inverters and combiner boxes. However, the indirect employment impact of deepening solar PV manufacturing is also significant. The World Bank has estimated that manufacturing has the highest indirect job creation multipliers

[114] These include those arising from the transformation of South Africa's electricity sector; significant increases in solar PV capacity and installations; the high growth in the emergence of small-scale solar generation (in the first five months of 2022, South Africa imported solar PV panels worth nearly 2.2 billion rand ($135 million), which amounts to over 500 megawatts of peak generating capacity.

in the economy: for every direct manufacturing job created, 3.8 indirect jobs are created.[115] Higher levels of local content generate increased employment multipliers.[116]

The changing domestic, regional, and global environment does offer opportunities for the deepening of South African manufacturing in solar PV value chains to serve the domestic and regional market and includes greater integration with the European solar PV value chain. The extent to which these opportunities are seized depend on both the actions of the South African government and on European partners.

4.2. Value chain opportunities and possible trajectories

The South African solar PV value chain is fragmented. However, important capabilities have been established which can be built upon, drawing on significant solar PV demand from:

- *South African demand:* A robust project pipeline combining public utility scale, private large-scale, commercial, and industrial and residential pipeline.
- *Export opportunities onto the rest of the continent* in the context of the AfCFTA. While the continent is not large relative to global solar PV demand, it is large relative to SA's current production capacity.
- *Exporting into the EU* based on preferential market access, meeting the EU's desire to diversify, greening production, institutional support including 'friend shoring' status, European development banks, assistance with investment recruitment.

Value chain opportunities are apparent in the following solar PV sub-systems.

Panel and module sub-systems. Entry into panel production is extremely challenging due to China's state-supported dominance of the panel value-chain. Competition will be further compounded by subsidies and other support measures being introduced by the US and the EU as well as the entry of two large developing countries: India and Türkiye into the solar PV market. However, two areas of opportunity stand out.

- First, opportunities for limited increases in localisation related to **module assembly** based on imported panels. This includes producing aluminium frames and adding substrate, glass etc. The potential introduction of a 10 percent import duty on imported modules would, if implemented, provide a modest level of support to the domestic industry. However, the impact on C&I and residential segments will need to be more fully assessed for whether the benefits of assembly outweigh a 10 percent cost increase, including whether tariff rebate mechanisms for this segment is advisable;
- A more challenging opportunity to be explored is whether South Africa can pursue panel value chain integration through attracting **investment in polysilicon**. Particularly desirable would be if feasible conditions could be established to produce green polysilicon using renewable energy. Drivers for such a scenario include the EU's desire for more diversified and sustainable supply chains, South Africa's silica deposits and abundant solar and wind resources and the advantage green polysilicon and its derivative products with respect to European CBAM taxes. As polysilicon comprises around 25 percent of the cost of a solar panel the establishment of 'green polysilicon' could pave the way for the further development greener production of the ingots, wafers, and cell parts of the value chain.

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[115] Group, *Focus on Private Investment for Job Creation*.
[116] Fiona Tregenna, *Sectoral dimensions of employment targeting*, International Labour Organization (Geneva, 2015), https://www.ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_346475.pdf.

An alternative scenario could be the attraction of Chinese investment in polysilicon as part of an emerging pattern of outward investments to mitigate potential risks to access to EU and US markets explored via inter industry discussions and potentially discussions with local DFIs;

- **Mounting structures and trackers.** Mounting structures and trackers are amongst the most developed solar PV sub-systems in South Africa, particularly for utility scale. High levels of overall local content are evident, and manufacturers are well placed to scale up to meet anticipated demand. The extent to which they can penetrate export markets, including the rest of continent and the EU, needs further assessment potentially through in-depth practical market identification and quantification, in particular via regional and international trade agreements, and including to the EU;
- **Cables.** Significant opportunities for import replacement of cables. The extent to which they can penetrate export markets, including the rest of continent and the EU, needs assessment. It will be important to quantify the size of the import replacement opportunity and identify a clear strategy for focussed import replacement, as well as practical short listing and quantification of the export opportunities in selected markets. The effectiveness of measures to prevent copper cable theft and prevent illegal exports will be an important determinant of the price at which recycled copper is available on the domestic market. There is potential to undertake the modelling of the economic relationship between volumes and value of cable theft, and availability of recycled copper.
- **Inverters.** While South African imports a considerable proportion of both string and centralised inverters there is scope to attract investment. This includes exploring whether the two major global inverter manufacturers that invested in manufacturing facilities in SA, but closed due to REI4P rollout delays, could be attracted back into the SA market. Unlike panels and some other systems, a number of dominant inverter manufacturers are European;
- Scaling up of parts **electrical balance of plant** with the potential to scale, including switchgear, solar charge controllers and monitoring systems and transformers.

These value chain opportunities are summarised in Figure 15 below.

Figure 15: Value chain opportunities

Modules	Mounting Structures and Trackers	Cables and Combiner Boxes	Inverters	Balance of Plant: Electrical	Balance of Plant: Civil	End of Life Management
Lamination	Steel profiles	AD/DC cables	Centralised inverters	DC and AC network (cables)	Installation, logistics, construction	Recycling of panels
Junction Box	Aluminium profiles	Conductors (copper, aluminium rods)	Magnetics	Surge protection devices	Access roads and gates	Reuse (panels, structures, inverters)
Aluminium Frames	Tracker communication boxes	Insulation (polymers)	Enclosures	Switchgear	Miscellaneous site civils (drainage, field prep)	Recycling of steel structures and electrical components
Super-Substrate (glass)	Brackets and clamps	Armour (steel)	Transformers	Charge controllers and monitoring systems (excl. semi-conductors)	O&M buildings	
Copper wiring		Combiner boxes	Circuit boards	Conduits and fittings		
Backing Sheet		DC cables connectors	Power stage and electronics	MV/HV transformer		
Ethylene Vinyl Acetate		Normal cables	String Inverters	Earthing grid		
Silicon				Control room		
Poly/ monosilicon						
Ingots and Wafers						
Cells						

Source: Authors' analysis, based on SAREM (2023) and SAPVIA (2022).

Moderate support measures and capabilities development required
Intermediate support measures and capability development required
Intensive support measures and capability development required.

Although the study involved engagements with a number of European industry associations and representatives it did not extend to engagements with OEMs around the sub-systems and components that are in demand and which South Africa could be well positioned to supply. Accordingly, one of the recommendations below include a joint South African / European targeted investment recruitment drive to pin down solar PV components that South Africa could best be suited to provide a more diversified supply base predicated on the development of a greener and more socially responsible supply chain.

4.3. Policy options and recommendations: South African Government

4.3.1 Policy certainty

Greater policy coherence and certainty is required. Manufacturing to supply the solar PV (and broader renewables) market has been hampered by significant uncertainty related to policy formulation and implementation. Notable have been delays in concluding BWs 4 and 5, conclusion of power purchase agreements; changes to localization policy not necessarily well calibrated to supply conditions and more recent uncertainty about the preferential procurement regime as a whole; restrictions until recently on licensing private renewables projects; and delays in concluding policy documents including updating of the IRP and finalisation of the New Energy Vehicles (NEV) Roadmap.

The IRP needs to be updated on a predictable and more frequent schedule. The imminent publication of an updated IRP is welcome and hopefully ushers in the practice originally envisaged of updating the IRP every two years.

Policy instruments to support localization need reconfiguration. Localization requirements linked to preferential procurement legislation have been dramatically watered down in the draft preferential procurement legislation being finalized, with any socio-economic objectives collectively relegated to no more than a 10 percent price preference (for projects over ZAR50m). The REI4P appears to have followed this trajectory with for instance the recent bid window for battery projects allocating an effective 0.78 percent price preference for local content. In the context of the more limited role of the preferential procurement act the REI4P needs to promote ambitious yet realistic local content targets. This could include negotiating an exemption from preferential procurement legislation and regulations with National Treasury to embed localisation requirements that go beyond some fraction of the 10 percent price preference. This should be a key outcome of the SAREM process currently underway and could be advanced in the SAREM going forward.

Trade policy coherence and certainty is required, particularly with respect to tariff measures. This matter is under discussion and consultation currently; However, a clear stance is needed as soon as possible.

The recently approved **Green Hydrogen Commercialisation Strategy**, when made public, should give a stronger indication of the demand for solar PV required for GH2.

The **New Energy Vehicles Roadmap** needs to be finalised, including projected additional demand it will place on the energy system and associated increase in demand for solar PV supply.

4.3.2 Incentives and concessional financing

The review of international policy measures conducted in Chapter 3 reflects that **no country that is pursuing solar PV (and other renewables-linked) manufacturing ambitions is doing so without significant public on- and off-budget support**. A wide range of support measures are being deployed including fiscal incentives, concessional finance through development banks and other supportive policies by China, US, EU, India, Türkiye.

By contrast, **South Africa has no dedicated fiscal support for green manufacturing** in place, either in the form of grants or tax incentives. The current fiscal stance is one of consolidation, with weak economic growth dampening tax collection. On-budget incentive support for manufacturing in general has been in decline for several years. However, as proposed by the SAREM, an appropriately structured tax incentive can and should be implemented to support investments at scale in catalytic projects in green value chains, including solar PV. This would involve a **"no-regret" tax incentive that is tailored to apply only to projects which create new value chain capabilities or are otherwise catalytic expansions** by promoting a minimum capacity addition scaling up in existing activities.[117] Such an incentive would at worst be tax revenue neutral: if no firms apply or are approved. Since it would generate new economic activity or a step increase in existing capacity it would begin to generate tax income as soon as an approved project begins operation. This will occur through payroll taxes and stimulation of up and downstream activity and the project will become a full corporate tax paying entity when the incentive expires. SAREM proposes that the existing (but expired) Section 12i tax incentive in the Income Tax act could rapidly be re-activated and re-purposed as a catalytic green industry tax incentive. In addition, the expired Section 12l of the act, which previously provided support investment in energy efficient projects should similarly be explored for re-activation.

Manufacturing linked to the smaller scale commercial and industrial, and residential SSEG demand should be stimulated by **adding a local content premium to the tax incentive offered to businesses and households to install rooftop solar** and be extended to other system components including inverters.

Further scope for rendering the tax code fit for purpose to support a green manufacturing transition is to explore amendments to **Special Economic Zones** governed by Section 12E of the Income Tax Act, to encourage both the manufacturing of solar PV and other renewable and green industry components and to green the energy supply of these zones. This would include expanding the range of activities supported to include the installation of renewable energy and storage to green the electricity supply of SEZs (and could include other circular economy measures, including e.g., water use, waste management etc.). It should also include expanding the applicability of the act to additional SEZ's. For instance, the Atlantis Special Economic Zone for Green Technologies does not currently benefit from Section 12E provisions as it has not yet been designated an SEZ in terms of the Act. In this regard lessons can be learned from other countries, including Ethiopia's ambitious industrial parks programme.[118]

As discussed below on actions that can be taken by EU partners, the role of concessional finance through development banks is extremely important. This includes potentially drawing on JET-IP (Just Energy Transition Investment Plan) funds for solar PV manufacturing together with other financing from European multilateral and national development banks. This includes institutions such as the European Investment Bank (EIB) and Kreditanstalt für Wiederaufbau (KfW).

4.3.4 Targeted investment recruitment drive

As emphasized by development economists such as Hausmann and Rodrik [119] and Evans [120] investment opportunities, and associated coordination and action of public entities cannot be identified in a vacuum. They require structured engagements between public sector actors and potential and existing investors which balance willingness to extend state support with maximizing benefits relative to the costs of such support.

[117] For instance, for the expansion of production by not less than 100%.
[118] Oxford University Press (2023). The Oxford Handbook of Industrial Hubs and Economic Development. Eds Arkebe Oqubay and Justin Yifu Lin.
[119] Hausman, R., & Rodrick, D. (2003). Economic development as self-discovery. Journal of Development Economics 72/2, Pp 603-633
[120] Evans, P. (1995). Embedded autonomy: States and industrial transformation. Princeton University Press

Accordingly, it is proposed that a joint South Africa / European **targeted investment recruitment drive** is undertaken to identify potential investors in key value chain sub-systems and engage on how South Africa's mix of solar and raw material endowments, existing industrial and institution capabilities and support mechanisms, and concessional financing by international partners could be brought to bear to attract or expand investment in the South African solar PV value chain. This involves systematically identifying key OEMs, and first and second tier suppliers in each relevant sub-system and a structured programme of engagement with each of these firms. This includes international OEM's and component suppliers as well as relevant domestic firms.

Indicatively some sub-systems should be targeted for more detailed analysis and engagement with potential investors:

- Exploring whether South Africa can pursue panel value chain integration through **attracting investment in polysilicon**. Particularly desirable, would-be green polysilicon using renewable energy. Drivers for such a scenario include the EU's desire for more diversified and sustainable supply chains, South Africa's silica deposits and abundant solar and wind resources and the advantage green polysilicon and its derivative products with respect to European Carbon Border Adjustment Mechanism (CBAM) taxes;
- Exploring how currently fragmented parts of the value chain could be combined to develop a value proposition for producing and exporting a package of componentry onto **the rest of the continent** and into the **EU's burgeoning rooftop solar market**. This would require considerable value chain integration and cooperation including price moderation on steel and aluminium products, intermediate investments in aluminium extrusion for frames, building on relatively well-developed capabilities in areas such as mounting structures and trackers and cabling, and building stronger capabilities in inverters and electrical balance of plant with the capacity to scale. For the rest of the continent consideration should be given to developing production for and targeting specific high-growth segments such as mining and commercial and industrial projects, in selected geographical markets. Export insurance and credit products would be an important element of such a package. More challenging is to develop a value proposition for the EU market. Greater emphasis is likely to be required on sustainable and circular economy production principles which are amenable to production within "Green" SEZs.

As articulated above, attainment of economies of scale are critical. Economies of scale require shifting beyond a focus on the South African market alone, to export opportunities. These include **targeting investment opportunities to supply the rest of the continent as well as potential to supply the European market** in alignment with its ambition to raise its prior targets of solar PV installation and supply chain diversification.

Broadly two possible investment recruitment strategies are evident. First, to engage European OEMs on their appetite to (re)enter the South African market. Such an engagement would emphasize the value proposition South Africa offers in terms of developing a supply in line with just energy transition principles emphasizing, greening of the supply chain and decent working conditions. The second potential strategy is to engage with lead Chinese OEMs who are increasingly concerned with preserving market access to the US and EU. Such a strategy would emphasize South Africa's market access to the EU through EU-SA FTA and to the US under AGOA. A precedent for geographic diversification of Chinese investors is already evident from, for instance, recent battery mineral related investments made by Chinese firms in Morocco[121] with a view to accessing the US and EU markets.

4.3.5 Standards and testing

International standards for the various components (especially inverters) and modules are globally accepted as a baseline for the various components, modules, and activities along the value chain. Many OEMs require the standard tests as well as specific additional tests to be undertaken, depending partly on the application for which the panels are intended. While there are some testing facilities in South Africa, the CSIR is the only such facility with a wide range of testing capability that goes significantly beyond the basic testing required by these OEMs. This may represent an opportunity for collaboration between EU testing laboratory groups and South African universities and laboratories as partners to increase South African capacity and quality. Currently, OEMs based in South Africa intending to export to the EU and other jurisdictions with very specific testing and certification requirements could need to have the tests conducted offshore, at a higher cost. This would represent a barrier to export of South African manufactured components and modules if there is no expansion of facilities and capabilities.

4.3.6 Skills development

While in the early stages of the solar PV industry development no specific certifications were required. With more stringent requirements from municipalities and more informed clients from residential to large scale projects, installers can no longer, as in the past, do installations without presenting some proof of being qualified to do the work properly. Energy and Water Sector Education and Training Authority (EWSETA) CEO Mpho Mookapele said the entity usually received skewed information on what skills the country required as the RE sector matures. The EWSETA has been working with industry associations SAWEA and SAPVIA to help determine the correct skills demand profile in the RE sector as it is not yet finally established. According to SAPVIA, the skills shortage in the RE sector is particularly prevalent in the solar PV industry, as a spike in PV uptake has laid bare a huge shortage of capable people to install these systems, especially in the residential market.[122]

There is a need for a wider range of training. Currently, SANEDI and SARATEC as well as the Cape Peninsula University of Technology (CPUT) all offer accredited short courses for interested learners. Other credible courses are offered by the Green Solar Academy which offers the SuperSolarSchool and Solar Power Designer for Commercial courses which have CPD accreditation from the South African Institute of Electrical Engineers (SAIEE); SineTech Energy is an endorsed “SuperSolarSchool” that offers a course that has been accredited by the German Solar Energy Society and is internationally recognised; and the Electrical Contractors Association offers courses on solar PV installations. However, if current market demand rates continue, it is likely that a wider range, as well as more and different content will be needed soon.

It is suggested that a summit could be held between SAPVIA, SAWEA, Manufacturers and trainers in 2024 to identify skills needs and develop a core list of essential skills, and curriculae that are internationally acceptable and can be developed and implemented. Training can take place (short

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[121] Financial Times (2023). Chinese battery groups invest in Morocco to serve western markets. [Chinese battery groups invest in Morocco to serve western markets (ft.com)]

[122] Engineering News (2023). *Renewable energy skills shortage major challenge to sectors growth.* https://www.engineeringnews.co.za/article/renewable-energy-skills-shortage-poses-major-challenge-to-sectors-growth-2023-06-22

courses) on a rotational spatial basis, possible using local Tertiary Vocational Education and Training) (TVET) facilities, so that opportunities are made available to young people and women (who typically are not always able to attend courses due to household and familial duties) in rural and urban areas. Inclusion in the courses could speak to pre agreed and specific GESI targets to increase the inclusion of women and youth as the market continues to grow. This could be potentially funded by the EWSETA, the YES and other similar funding programmes, as well as allocations from large firms possibly through entities such as Harambee. Training can be localised and synchronised ahead of known installations in cooperation with developers as small and larger areas switch to solar PV across the country.

4.4. Recommendations: European Partners

There are a number of actions that European partners can take to promote greater integration of South African with European solar PV value chains that deepen South African solar PV manufacturing. Engagements with European industry representatives indicate a desire to have a more diversified, greener, and more socially responsible supply chain. South Africa with its excellent renewable resources, established – albeit uneven – manufacturing capabilities and robust labour laws is a good potential partner. However, these industry representatives also indicated that they remain under substantial price pressures from China in particular, and that the likelihood of any environmental and social price preference would be unlikely. In order to square the ambition of diversified, greener and more socially responsible supply with the lack of any price preference, European partners can promote value chain integration through other actions.

First, SolarPower Europe and other stakeholders can play a key role in a **targeted investment recruitment drive** that links and encourages European companies to invest in and procure from South Africa based manufacturers. Such a collaboration should ideally position South Africa as a more green and ethical manufacturing supply base aligned to European ambitions of sustainability and high ESG (Environmental, Social and Governance) standards that can produce at the scale and quality necessary for the European market.

Second, to assist in securing sources of **concessional funding**. This should include grant and low-cost debt funding that goes beyond commitments already made in JET-IP. European investment banks, such as the EIB and KfW have a vital role to play in supporting project development including pre-feasibility studies, feasibility studies and co-funding with private investors and South African development banks.

Third, **technical assistance** in areas including skills development and standards testing and accreditation facilities.

5. Annexures

Annexure A: Detail of international and domestic standards required for solar PV and related inverters.

International standards- detail

There are several main international standards in place for solar PV modules. These include the main standards as follows:

- **IEC 61215** (International Electrotechnical Commission)- specifies design and type approval requirements for crystalline silicon terrestrial PV modules. It covers aspects like mechanical integrity, electrical safety, and environmental testing;
- **IEC 61646** (International Electrotechnical Commission): Like IEC 61215, IEC 61646 is the standard for thin-film terrestrial PV modules. It outlines requirements for their design, safety, and performance;
- **IEC 61730** (International Electrotechnical Commission): This standard focuses on the safety of PV modules. It includes testing for resistance to environmental factors, electric shock, and fire hazards;
- **IEC 61701** (International Electrotechnical Commission): IEC 61701 specifies the test procedures for salt mist corrosion testing of PV modules, ensuring their durability in marine environments;
- **IEC 62716** (International Electrotechnical Commission): This standard covers the testing of PV modules for potential-induced degradation (PID), a phenomenon that can reduce module performance;
- **UL 1703** (Underwriters Laboratories): This is a U.S. standard that covers the safety and performance requirements for PV modules. It ensures that PV modules are safe for use in the United States;
- **ISO 9001** (International Organization for Standardization): While not specific to PV modules, ISO 9001 is a general quality management standard often adhered to by PV module manufacturers to maintain consistent quality in their products;
- **ISO 14001** (International Organization for Standardization): This standard deals with environmental management systems and is often implemented by PV manufacturers to reduce the environmental impact of their operations;
- **ISO 50001** (International Organization for Standardization): ISO 50001 addresses energy management systems and is relevant for PV module manufacturers looking to optimize energy use in their production processes.
- **CEN/CENELEC Standards** (European Committee for Standardization and European Committee for Electrotechnical Standardization): In Europe, the SolarKeymark certification scheme references various CEN and CENELEC standards for solar thermal and photovoltaic products, including PV modules.

Manufacturers typically test their products to comply with these standards, and third-party certification bodies may verify compliance. IEC 61215 testing simulates temperature or/and humidity conditions by putting the modules through specific tests that measure environmental, performance, mechanical and safety aspects of the solar panel. IEC 61215 consists of 19 Module Quality Tests

EU Standards- detail

The EU adheres to various international standards for solar PV, including those issued by the International Electrotechnical Commission (IEC) and the European Committee for Standardization (CEN). These standards cover aspects like system design, performance, safety, and environmental impact. The EU has established certification procedures to ensure that PV modules and systems meet the prescribed standards. Bodies like the SolarKeymark and national certification organizations play critical roles in this process. For residential systems, aspects such as module efficiency, durability, and electrical safety are covered and for utility scale, there are strict guidelines to ensure the stability and reliability of the grid. At utility scale, there are also strict environmental requirements, including guidelines for land use, wildlife protection, and waste management in the context of large solar installations. The following list is not exhaustive but offers a view of the regulatory and testing requirements of the EU.

- **Renewable Energy Directive (RED**) - Directive 2009/28/EC: This directive sets the framework for promoting the use of energy from renewable sources, including solar PV, in the EU;
- **Energy Efficiency Directive (EED**) - Directive 2012/27/EU: While not specific to solar PV, this directive sets energy efficiency goals that can indirectly impact the deployment of energy-efficient technologies such as PV;
- **Low Voltage Directive (LVD)** - Directive 2014/35/EU: LVD addresses electrical safety aspects, which are essential for solar PV systems, especially at the residential level;
- **Electromagnetic Compatibility Directive (EMC**) - Directive 2014/30/EU: EMC ensures that PV systems do not cause electromagnetic interference and can operate harmoniously with other electrical equipment;
- **Grid Connection Codes-** These are a set of regulations, and they may vary by country, which govern the connection of solar PV systems to the electrical grid. They can be found in various national energy laws and regulations;
- **Eco-Design Directive** - Directive 2009/125/EC: This directive sets eco-design requirements for energy-related products, including PV modules, to improve their environmental performance;
- **SolarKeymark** - CEN/CENELEC Standards. The SolarKeymark is a voluntary certification scheme for solar thermal products, and it references specific CEN and CENELEC standards that are relevant to solar thermal collectors and systems;
- **WEEE Directive** - Directive 2012/19/EU: The Waste Electrical and Electronic Equipment Directive addresses the proper disposal and recycling of PV system components at the end of their life cycle;
- **RoHS Directive** - Directive 2011/65/EU: The Restriction of Hazardous Substances Directive restricts the use of certain hazardous substances in electrical and electronic equipment, including PV components; and
- **Energy Performance of Buildings Directive (EPBD**) - Directive 2010/31/EU: While more focused on building energy performance, this directive indirectly affects the integration of solar PV into buildings and their energy efficiency.

The following are required by South Africa, for any imports of solar PV modules into the country (amongst other documentation).

- **SABS Mark-** Products that meet South African standards will carry the SABS mark, indicating their compliance with local regulations. Manufacturers must ensure their products adhere to South African standards like SANS 61215 for crystalline silicon terrestrial PV modules;

- **IEC Certification** -Having International Electrotechnical Commission (IEC) certification can be advantageous. South African authorities recognize IEC standards, and IEC certification can demonstrate that the modules meet international requirements;
- **Certificate of Conformity** (CoC)- Importers may be required to obtain a Certificate of Conformity from a registered inspection agency in the country of origin. This certificate affirms that the products comply with South African standards; and
- **Product Data and Technical Information-** Detailed technical information, including specifications, test reports, and user manuals, are required to accompany the shipment to provide evidence of the product's quality and performance.

South African standards and testing

The South African Bureau of Standards (SABS) is responsible for establishing and maintaining standards for solar PV modules. SANS 61215 is the South African National Standard, based on the International Electrotechnical Commission (IEC) standard IEC 61215, and outlines the requirements and test methods for crystalline silicon terrestrial PV modules. It covers aspects such as design, safety, and performance. The standard ensures that PV modules used in South Africa meet the necessary quality and safety criteria.

Exporting solar PV modules from South Africa to the European Union (EU) involves ensuring that the modules comply with both South African and EU standards. The main standards and tests are:

- **SANS 61215 Compliance**: solar PV modules manufactured in South Africa should comply with SANS 61215, the South African standard for crystalline silicon terrestrial PV modules. This standard encompasses various tests related to the design, safety, and performance of PV modules.
- **IEC Standards**: Many South African solar PV module manufacturers also test their products to comply with international standards set by the International Electrotechnical Commission (IEC), such as IEC 61215 for crystalline silicon PV modules or IEC 61646 for thin-film PV modules.
- **Comprehensive Testing:** solar PV modules need to undergo a range of tests, including electrical performance, thermal cycling, humidity freeze, and mechanical load tests to ensure their quality, safety, and durability.

The following certificates are required for exporting to the EU:

- **CE Marking-** solar PV modules exported to the EU need to have CE marking. CE marking indicates that the product complies with EU health, safety, and environmental protection requirements. It is a mandatory conformity marking for products sold within the European Economic Area (EEA), which includes the EU member states;
- **IEC Certification**- It is beneficial for South African solar PV modules to be IEC certified, as this demonstrates compliance with international standards. The IEC certification is widely recognized in the EU and adds credibility to the product;
- **Certification by Notified Bodies-** In some cases there may be a need to engage with a Notified Body in the EU. These are independent organizations which assess and certify products to ensure they meet EU requirements;
- **Declaration of Conformity-** solar PV module manufacturers or exporters need to provide a Declaration of Conformity indicating that their products meet the necessary EU standards and regulations;
- **Environmental Certifications**- Some EU markets, especially for commercial and utility-scale PV installations require additional certifications related to environmental impact and

sustainability. These can include ISO 14001 for environmental management and ISO 50001 for energy management.

For components there are additional IEC tests for compliance, specifically in Balance of System such as:

- **IEC 62093:2005:** Balance-of-System Components for Photovoltaic Systems - Design Qualification Natural Environments
- **IEC 62109-1:2010:** Safety of Power Converters for Use in Photovoltaic Power Systems - Part 1: General requirements
- **IEC 62109-2:2011:** Safety of Power Converters for Use in Photovoltaic Power Systems - Part 2: Particular requirements for inverters
- **IEC 60269-6 ed1.0:** Low-Voltage Fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems.

There are multiple other IEC tests for elements and components of solar PV systems and their performance and connections and often the off taker will specify the nature and combination of certifications required.