INSIGHTS INTO THE SOLAR PHOTOVOLTAIC MANUFACTURING VALUE CHAIN IN SOUTH AFRICA

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ABBREVIATIONS AND ACRONYMS

BOP	Balance of Plant
BOS	Balance of System
EPC	Engineering, Procurement and Construction
EU	European Union
FIT	Feed-in Tariff
IEC	International Electrotechnical Commission
IPP	Independent Power Producer
IRP	Integrated Resource Plan
ITC	International Trade Centre
MW	Megawatt
NERSA	National Energy Regulator of South Africa
OEM	Original Equipment Manufacturer
PV	Photovoltaic
RE	Renewable Energy
REI4P	Renewable Energy Independent Power Producers Procurement Programme
SADC	Southern African Development Community
SAPVIA	South Africa Photovoltaic Industry Association
SAREM	South African Renewable Energy Masterplan
SSEG	Small-scale Embedded Generation
USD	United States Dollars

1. INTRODUCTION

The South African Integrated Resource Plan (IRP) 2019 provides that by 2030 the electricity generation mix will comprise 8 288 megawatts (MW) or 10.6% Solar Photovoltaics (PV). Distributed or embedded generation for own use is expected to add 4 000MW between 2023 and 2030 (the dtic, 2021).

By the end of December 2021, active Solar PV capacity through the Renewable Energy Independent Power Producers Procurement Programme (REI4P) was 2 212MW, or 97% of the 2 292MW procured. Forty-two Solar PV projects had at that point been operational for more than one year (IPP Office, 2021). Furthermore, the procurement of electricity in Bid Window 5 of the REI4P could begin adding capacity from early 2024, and the amount of new generation capacity procured through Bid Window 6 (for wind and solar power) will be doubled from 2 600MW to 5 200MW (Ramaphosa, 2022).

Outside of the REI4P, electricity market reforms recently announced, promulgated or gazetted for comment will result in a large increase in private industrial, commercial and, possibly, municipal projects. These include amendments to the Electricity Regulation Act No. 4 of 2006 which was amended on 12 August 2021 to increase the licensing exemption threshold to 100MW. Since then, a total of 479MW of generation capacity has been registered with the National Energy Regulator of South Africa (NERSA), compared to 188 MW before that. Most of the projects are based on solar PV technology (at 86% of total reported generation capacity) (Montmasson-Clair, 2022).

With the July 2022 Presidential Electricity Plan announcement of the total removal of the licensing threshold for embedded generation, these numbers might well increase dramatically. Furthermore, for the small-scale embedded generation (SSEG) market (which is often rooftop Solar PV), generators should be able to sell electricity to the grid, with Eskom to announce a feed-in tariff (FIT) (Ramaphosa, 2022) and this will also drive further uptake of Solar PV.

Changes to localisation requirements for Bid Window 5 Solar PV have also since been announced: the share of PV modules that must be manufactured in South Africa has dropped from 100% to 35%. This short-term measure is likely to be progressively increased again in future Bid Windows as the focus of the current South African Renewable Energy Masterplan (SAREM) process and draft strategy is to increase localisation of manufacturing. This seeks to improve local capabilities, increase jobs and investment, and expand exports (the dtic, 2021).

Overall, the push for more electricity generation, particularly renewable energy generation, is likely to result in a significant increase in Solar PV projects across the country. This is turn will drive demand for the components and services. Given this context, and to add to the existing body of knowledge on the Solar PV manufacturing value chain, this report provides insights on:

- Inverter manufacturing.
- Mounting frame manufacturing.
- Materials for Solar PV.
- Imports and exports of Solar PV components.

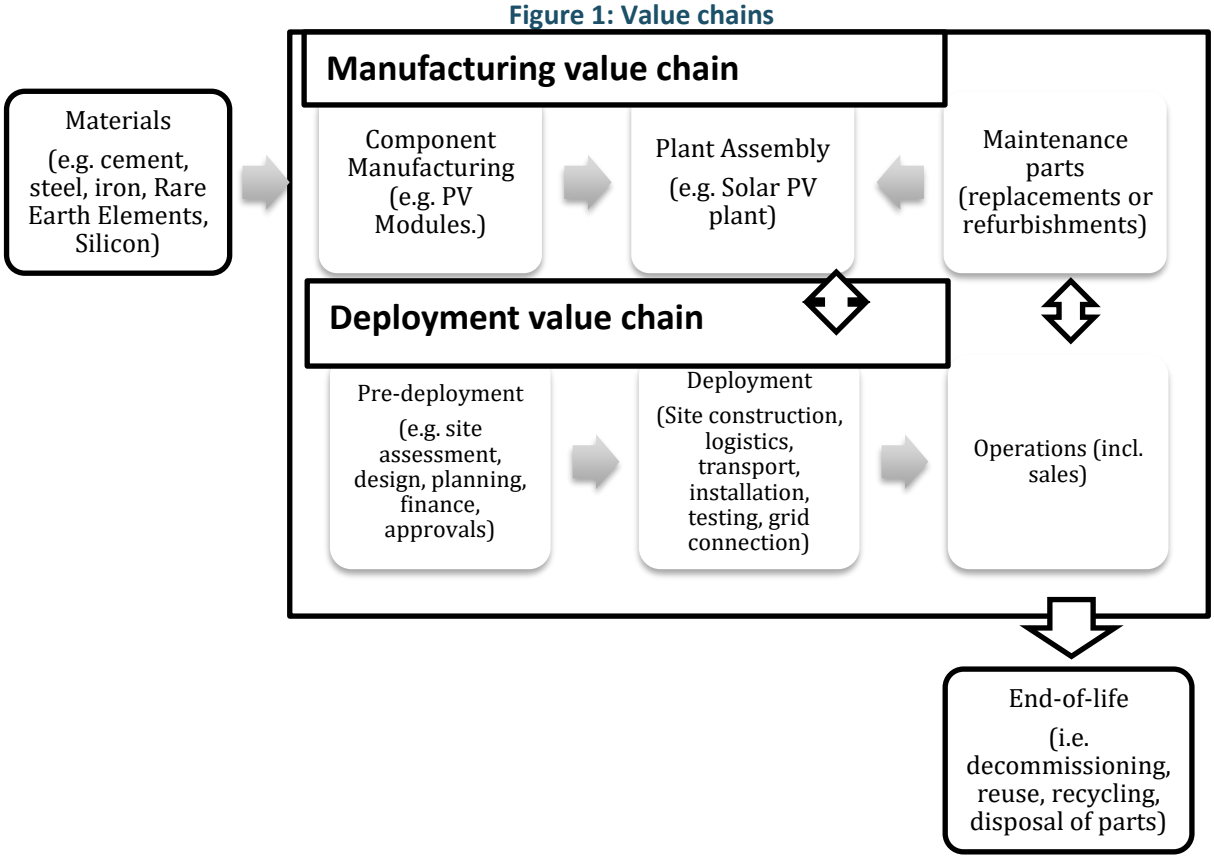
2. BACKGROUND: DESCRIPTION OF THE VALUE CHAIN

The value chain can be depicted two ways:

- In terms of *project deployment phases*: from conception to delivery, operations, then end-of-life or decommissioning.
- In terms of the *manufacturing value chain*: materials, manufacturing, assembly and delivery of the main equipment, as well as its maintenance or replacement.

Figure 1 shows these two value chains and how they interact, including the backward linkages to materials for the manufacturing chain and the forward linkages to end-of-life for renewable energy (RE) materials. While there is some time before the operational phase of South Africa's solar-based plants comes to an end, and it might be possible to extend the lifetime of certain plants, or replace certain parts, it is nonetheless worthwhile considering the circularity opportunities that exist, as well as some of the waste-related challenges from RE. In the shorter term this may be particularly relevant for the smaller-scale solar rooftop installations.

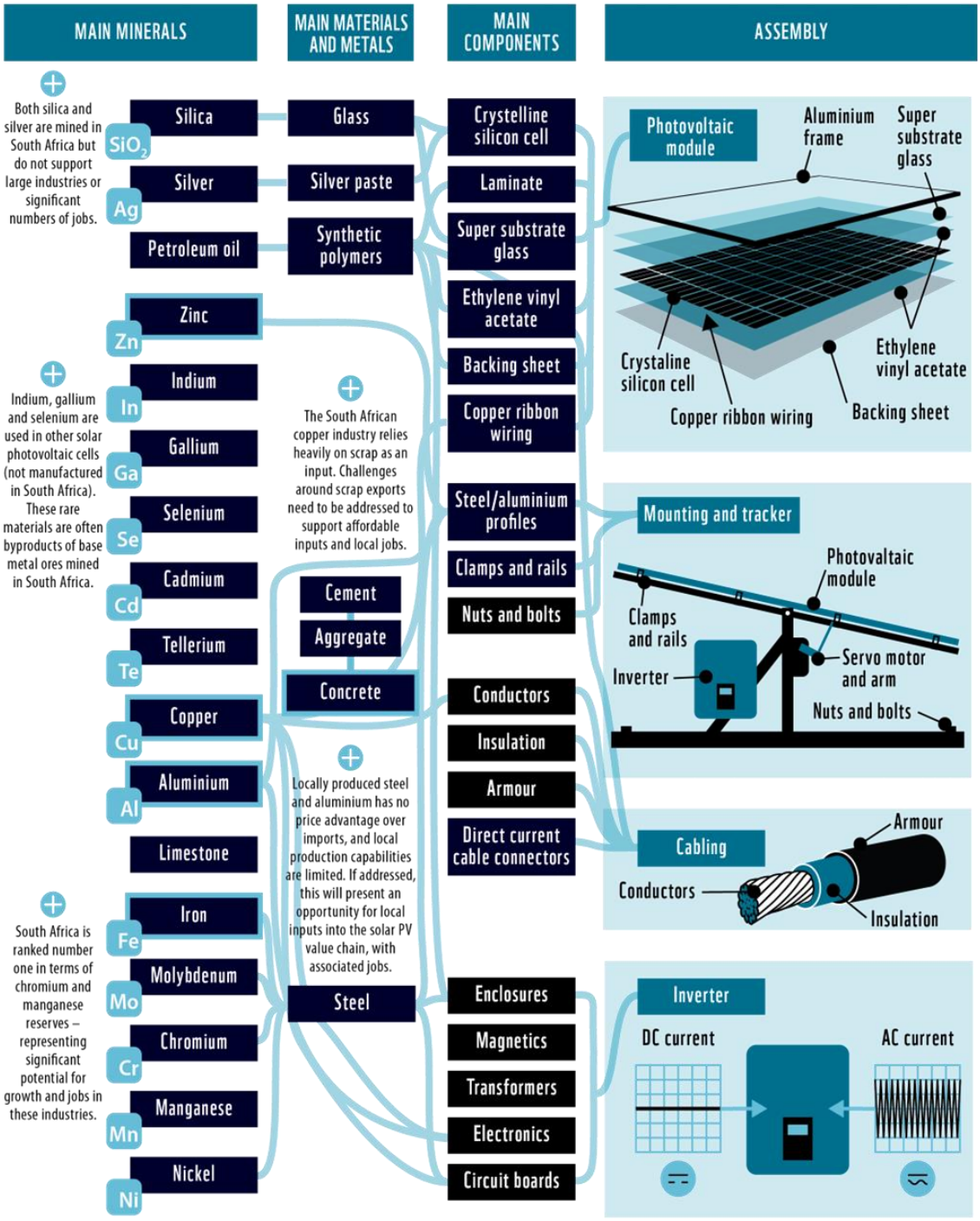
Figure 1: Value chains

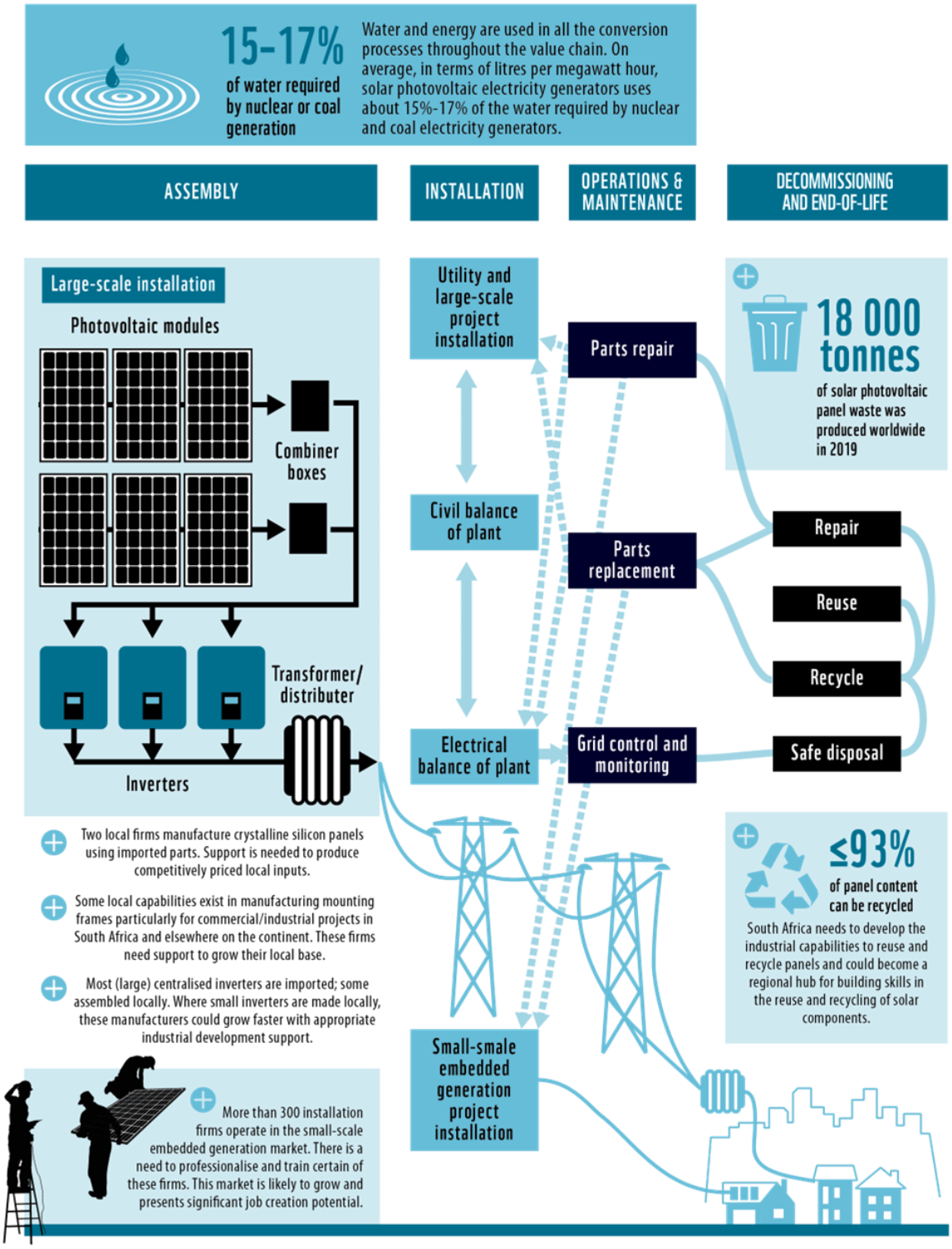


Source: Author

A detailed view of the manufacturing value chain for Solar PV, from materials to end-of-life, is provided in Figure 2.

Figure 2: Materials and manufacturing value chain for Solar PV – Opportunities for South Africa





Source: Adapted from Author, designed by WWF South Africa

The small-scale, mainly rooftop, solar market for households and commercial installations is typically far simpler in design and execution than utility-scale construction and operations. For this reason, it involves fewer players and steps in the value chain, and less componentry (as this is often standardised and not project-designed). For rooftop household Solar PV, the work is usually undertaken by one firm whose services include business development, technical assessments, solution design and engineering, as well as engineering, procurement and construction (EPC) and installation (Chown, 2021).

Firms involved in large and utility-scale projects include investors and financiers, project developers, Original Equipment Manufacturers (OEMs), power producers, consultants, EPC firms, component and subcomponent wholesalers, and manufacturers of components, among others.

While this report focusses on manufacturing inputs, there is also an array of services required by the Solar PV market; many are required in the project deployment phase. Larger private projects undertaken for industrial firms and large commercial operations often have certain similar – extensive – requirements to those of the REI4P projects. These include the need for site studies, financial structuring, technical specifications and design, as well as a range of compliance studies and documentation. Large projects outside the REI4P have fewer contractual requirements when it comes to local content minimum thresholds and targets which, for the REI4P, have been increased over the course of the bid windows[1] (but recently decreased to expedite the delivery of Bid Window 5 projects).

Project developers of the larger non-REI4P Solar PV projects are also able to negotiate offtake agreements with clients that are not subject to the pricing regime of the REI4P. The recent announcements regarding electricity market reforms, which allow private players to wheel and sell back into the grid, is likely to see strong growth in this private market although this will not necessarily translate into greater procurement of components that are locally manufactured.

While neither is comprehensive, two sources of data exist for firms providing goods and services into the Solar PV value chains in South Africa.

GreenCape provides one such list (see Annexure A) of local Solar PV specific component wholesalers and manufacturers.

The main industry association, the South African Photovoltaic Industry Association (SAPVIA), also has data on members although not many are local manufacturers. The full SAPVIA list of members[2] across membership categories is provided in Annexure B.

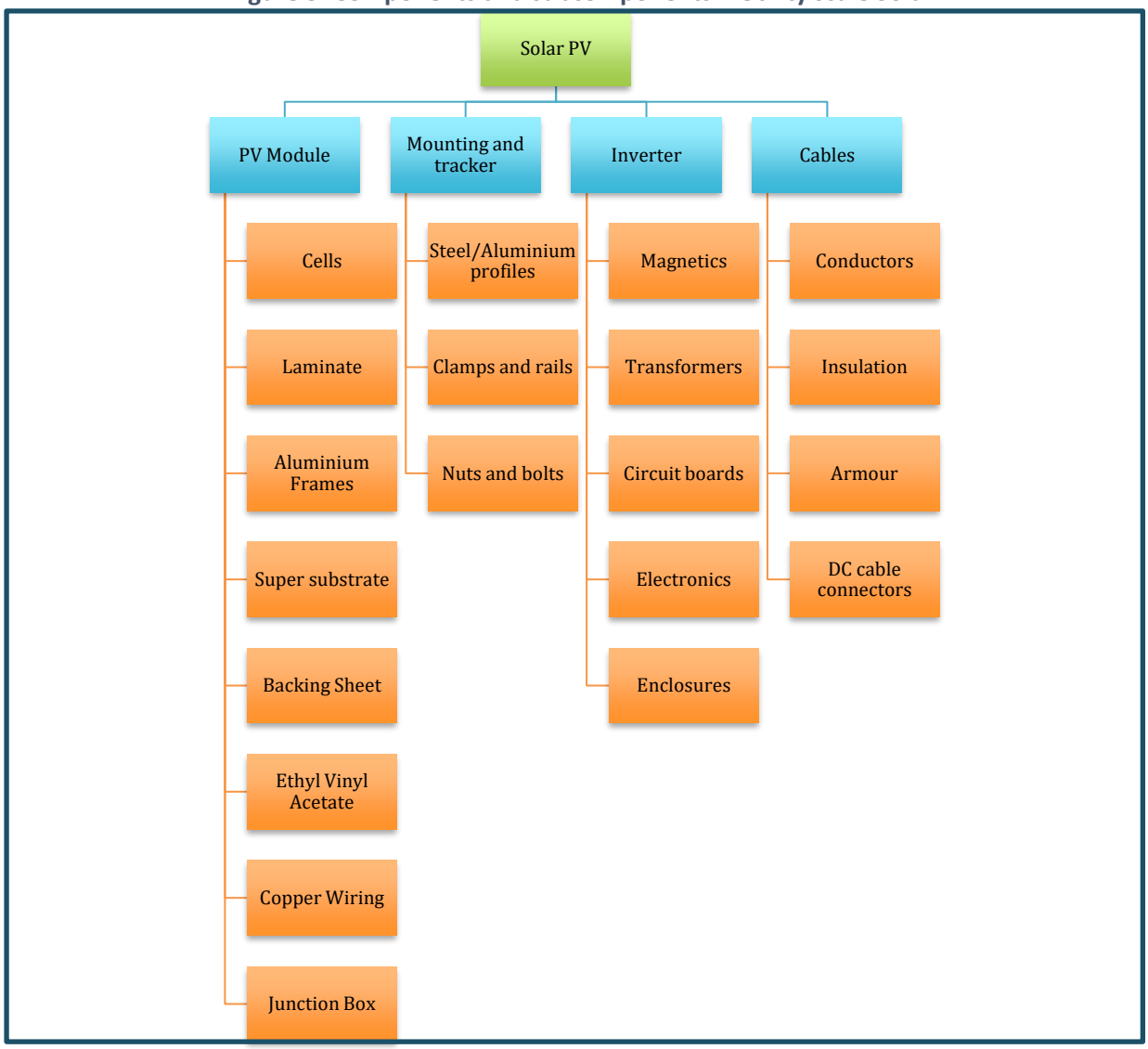
3. SOLAR PV COMPONENTS AND SUBCOMPONENTS

The main components of a solar-based system are the PV module, the inverter, the mounting structure, the tracker, and cabling. Mounting structures and trackers are often procured together as part of the same design process or pre-manufactured unit.

Large Solar PV projects also involve investments in the Balance of Plant (BOP), also sometimes referred to as the Balance of System (BOS). This refers to those parts of the system for capital expenditure that do not include the PV module. The BOP is generally broken down into logistics and installation, civil and electrical services and components. South Africa's established civil engineering, construction, and electrical services' capacity has meant most of these elements have readily been provided by local companies in the first bid rounds of REI4P. An exception is the parts of the electrical BOP where much is imported (DMRE, the dtic and DSI, 2022). Details of the main components and subcomponents are provided in Figure 3.

[1] By December 2021, local content commitments by Independent Power Producers (IPPs) had amounted to R66.3 billion of the project value realised of R127.2 billion (IPP Office, 2022.
[2] As available online in June 2022.

Figure 3: Components and subcomponents – Utility scale Solar PV



Source: Adapted from DMRE, the dtic and DSI, 2022.

There are opportunities for localisation of component manufacturing for both the large or utility-scale and SSEG markets. But, while the SAREM indicates that "South Africa has a solid base for manufacturing key components …, an extrusion industry for mounting structures, electro-technical expertise" (DMRE, the dtic and DSI, 2022:14), currently there are relatively few dedicated component and subcomponent manufactures in the Solar PV industry. For example, subcomponents for DC Combiner boxes are assembled in South Africa but not manufactured locally as firms do not manufacture according to the International Electrotechnical Commission (IEC) standards. And while manufacturing of AC cable is relatively well established and represented by firms such as Aberdare Cables and CBI African Cables, international cable suppliers continue to supply large shares of the market (Harmse, 2021). Only two local PV module-manufacturing firms exist – Seraphim and ARTSolar – and local mounting firms and inverter manufacturers are also few in number.

Locally manufacturing of inverters and mounting structures is considered in more detail below.

3.1 Spotlight on inverters

Inverters convert direct current output from PV into alternating current suitable to be fed into an electricity grid. They also typically provide a number of other capabilities such as data monitoring. For larger inverters, manufacturers may also provide technical service support to maintain optimal energy performance.

Inverters can be either centralised or string converters. String converters are smaller and joined together (through recombiners) while centralised inverters are large, single inverters that typically convert more power per unit.

String inverters are "mass production" type products. For large plants, these can be installed at scale by connecting multiple strings. The advantage is that inverters linked to strings can be replaced relatively easily if they break, without the plant losing significant energy generation. But this involves stocking many small inverters to replenish them, and the cabling of all the strings is far more complicated. String inverters are typically not designed to last as long as major centralised inverters (Guerra, 2022).

In South Africa, imported products dominate both inverter markets although some local manufacturing capacity also exists for both types.

Inverter wholesaling and manufacturing firms

GreenCape's database lists 3W Power (AEG Power Solutions), Microcare and MLT inverters as local inverter manufacturers, while firms selling imported Inverters are listed as Allsolar, ACDC Dynamics, Goodwe, ZRW Mechanika, Valsa, Huawei Technologies Africa, IBC Solar, Sinetech, Santerno South Africa, Schneider Electric, ABB, Siemens.

Two global firms, AEG Power Solutions and Germany's SMA Solar, the world's biggest manufacturer of solar power inverters, both previously set up local manufacturing facilities in South Africa (in around 2012) but closed these local manufacturing operations, reportedly due to delays in the REI4P roll-out (Moyo, 2016). AEG had invested in a 200MW per annum manufacturing facility of utility-scale solar inverters and Skytron Combiner Boxes (AEG Power Solutions, 2012).

While one South African manufacturer of local designed inverters, MLT Power, was successfully shortlisted as a supplier to a REI4P project in earlier rounds of the programme (Malengret, 2022), currently most centralised inverters for utility-scale projects are provided by Siemens, ABB, Ingeteam and Santerno South Africa[3].

Most of these larger inverter providers have local sales offices in South Africa but add little domestic value to the manufactured product. Of the major global players currently operating in the centralised inverter market in South Africa, Santerno South Africa, based in Kyalami, will in the future assemble inverters imported from Italy. They currently do all the cabling locally and provide technical support or maintenance contracts for the duration of the inverter contracts. (This is typically five years). The contractual conditions also vary in required support – in certain instances, a resident team of technicians resides on-site at the plant, usually for the term of the inverter contract; in others, a

[3] Part of Enertronica S.p.A, and while Enertronica works mainly as an EPC in Europe and Asia, Santerno produces inverters for industrial automation and power supply largely from solar installations, ancillary electrical and IT equipment including SCADA (supervisory control and data acquisition) solutions as well as engineering services for Grid Code Compliance (Guerra, 2022). Products include solar inverters and solutions, industrial automation and remote control and are supported by technical services.

remote maintenance contract is provided that includes telephone support and dispatches teams to site when required.

Santerno South Africa also provides operations and maintenance services, and sells spare parts. The firm is currently a shortlisted supplier to a number of REI4P Bid Window 5 project developers and, to date, has installed inverters for more than 600MW of power in South Africa. However, challenges with the REI4P have jeopardised investments in the manufacturing and local assembly of components for renewable energy in South Africa (Guerra, 2022).

Many inverter products at the small and cheaper end of the market are imported from China and India. These products include, for example, Mecer, Kodak, Sunsynk and Sungrow. These inverters products are transformer-less. For smaller inverters, Sunsynk is the most popular brand.

Microcare is a leading local manufacturer of smaller inverters with transformers. Its focus is on the rooftop market, including residential developments and office parks. Microcare's factory and sales office is in Gqeberha, Nelson Mandela Bay and the business has been operating since 1990. Rather than selling directly to the public or tendering for major contracts, Microcare works through trained installers across the country. The business has a number of products, with around 50 variations across its business lines.[4] However, while in 2015 Microcare was one of a few inverter brands available in South Africa, it now competes with well over 50 different brands (Burley, 2022).

Standards and performance

For REI4P projects, as suppliers to Original Equipment Manufacturers (OEMs), local manufacturers are required to meet the European Union (EU) electromagnetic interference standards as part of broader electromagnetic compatibility standards. These performance standards for devices must show that they are able to coexist with other devices. There are no South African laboratories that can provide assurance of these standards being met for locally manufactured inverters, and local firms have to send their inverters overseas for this testing, at great expense (Malengret, 2022).

For SSEG, certain imported inverters do not perform well in South Africa, but no local testing or certification of these inverters takes place. Installers seldom give customers a choice of what components to include and customers are not typically skilled to make an informed choice. Inverters that are not optimal for local conditions can affect performance, in turn creating a bad impression of inverters and Solar PV energy in general. A product quality-checking service is required to ensure that substandard products do not flood the market.

Employment and skills development

There is an opportunity to create employment in the inverter market. Firms require skilled technicians for wiring, testing and installation (Malengret, 2022). On-the-job training is also required, including for installers, with particular care necessary when working with centralised inverters. These are expensive pieces of equipment and require specialist skills.

Inverter specialists require two to three years of on-site experience after studies. There is an opportunity to cross-skill from electronic technicians, but inverters are highly specialised, expensive equipment, and are technologically specific as well. The market is in flux with a fair number of skilled

[4] The product lines include: bi-directional single and three-phase inverters, solar charge controllers, solar monitoring equipment providing online real-time data, single and three-phase solar pumps controllers, solar PV geyser solution, mini grids solutions for factories, businesses, game reserves with a scalable modules and contract manufacturing. Microcare has also recently developed a new solar water-heating product with a controller that takes solar power directly onto the geyser element. It involves dedicated PV panels that run the element. It is an efficient solution even in overcast weather and does not require batteries or plumbing.

technicians that leave and set up their own businesses once they have gained the specialised skills. Additional staffing for on-site training of local technicians has cost implications – and links to price competitiveness. Large players in the inverter market need to invest in building skills in South Africa. Also, South Africa competes globally for these skills and is not always viewed as an attractive destination (Guerra, 2022).

Santerno South Africa, for example, has a staff complement of 25 electrical technicians. Nearly all are on long-term contracts, which are linked to the warrantees and contracts with the Independent Power Producers (IPPs). These contracts often roll over from site to site. A small core office with aftersales, office administration and a sales manager is based in Kyalami. Santerno is setting up a local workshop for repairs to allow for further local services. This will service the power electronics and cabling (Guerra, 2022).

Microcare employs 70 staff, 50 of whom work in the manufacturing part of the business, supported by 20 staff in sales, marketing and administrative roles. The factory has the capacity to expand with its variety of products that range from mini-grids on the high end of services (valued at about R1 million each) to entry-level solar chargers (which typically cost only R1 000 each). Microcare offers training to its preferred installers to ensure that the technical products are correctly installed. It works with 300 installers in South Africa and the Southern African Development Community (SADC), with 30 being regular partners. There is a high turnover of installers, not all of which offer a professional service (Burley, 2022).

Components and subcomponents

Inverters are made up of a number of subcomponents, most of which are not supported by a domestic manufacturing base and, when they are, materials are often imported. Assembly, production and testing are, however, localised. Reasons cited for limited local manufacturing include quality issues in the case of power stage and power electronics (Harmse, 2021; Ramjee, 2021).

Even when subcomponents are bought in South Africa, they are usually imported from elsewhere. For example, a large share of the switchgear is imported. Power distribution transformers are, however, locally manufactured although there are relatively few manufacturers in this space too.

Ninety percent of the inverter subcomponents that are sourced and used by Microcare are manufactured locally. Imported subcomponents include the PC board (Microcare designs it but gets it manufactured outside the country), shunts (only available from a few factories globally) and caps. China has a strong hold on the market, which has resulted in copper prices on average increasing significantly over the past few years. This puts pressure on supply chains and pricing (Burley, 2022).

Growth potential

The current and new rounds and extended scale of REI4P as well reduced licensing requirements for private generation and private sales to the grid will likely result in expanded demand for inverters, although it does not automatically follow that the local industry will receive a boost from this. The ability of Inverter manufacturers to participate in RE14P is constrained by, among others, the requirement of performance bonds and the significant working capital necessary to withstand the long lead times until operational commencement (Guerra, 2022).

Microcare has the potential to expand in the domestic and regional small-scale inverter market (Burley, 2022) while foreign centralised inverter companies, often working with OEMs, may expand the range of services they provide in South Africa. While Santerno South Africa has recently announced it will extend services into repairs, for example (Guerra, 2022), other global centralised

inverter firms may also invest in larger local servicing and technical support if their local footprints are extended.

3.2 Spotlight on mounting structures

Mounting and tracking structures keep PV modules oriented in the right direction to the sun with consideration to each site and location. PV systems can be pole mounted, land mounted and/or rooftop/facade mounted, and they are either fixed or tracking (where they track the sun).

Mounting structure firms

According to the GreenCape database, manufacturers include KD Solar, SolarFrame and Caracal Engineering while wholesalers include Pia Solar, Valsa, K2 Systems, Sinetech, STI Norland, and LUMAX Energy (GreenCape, 2021).

Of the local manufacturing firms, Caracal Engineering is a seven-year-old company specialising in structural engineering services for mounting structures for Solar PV installations. Headquartered in Johannesburg, it delivers mechanical engineering, construction and product design services for commercial, industrial and utility-scale photovoltaic projects across Africa and the Middle East, and has completed over 105 projects to date. While Caracal works with EPC companies, it does not participate in the REI4P as that programme has a number of additional compliance conditions, making it less attractive to smaller players.

Standards and performance

Challenges affecting the industry include the relatively low barriers to entry for installers, and limited professionalism or vetting of installations. This leads to instances of substandard installations, particularly in the small-scale household rooftop market where expertise, service levels and pricing differ extensively. For this market, mounting structures for rooftop solar are typically imported and come in standardised sizes.

Access to concessional finance in South Africa is also constrained for small manufacturing firms, despite their local manufacturing and job creating impacts, as it can come with significant conditionality.

Employment and skills development

In the case of Caracal Engineering, the core office team consists of 15 people, made up of engineers, project managers and draftsmen. They are supported on-site by larger installation teams, up to 130 people at a time. There is accordingly significant opportunity for part-time work on-site and the development of some project specific skills, with the potential to transfer these across sites and projects if local demand grows (Venter, 2022).

Components and subcomponents

The main share of the cost of mounting structures is in the steel or aluminium profiles. Both metals sell at import parity pricing, so there is little price benefit to local procurement (Escience Associates, Urban-Econ Development Economics and Chris Ahlfeldt, 2013).[5] Price is the main factor challenging the competitiveness of South African steel and aluminium manufacturers. As a result, most local firms competing in the solar-mounting engineering space import materials and manufactured products.

[5] Caracal Engineering sources materials locally, despite competition from imports from wholesalers. (There are many steel and aluminium imports of mounting structures, mainly from the EU and Asia). In South Africa, local manufacturing suppliers offer a shrinking portfolio of products.

In terms of other subcomponents, specialist clamps are imported but nuts and bolts are locally sourced. STI Norland has invested in local capacity for trackers (Harmse, 2021; Ramjee, 2021).

Growth potential

Significant potential exists for increasing localisation in mounting structures off the back of the growth of the South African Solar PV market as well as its growth on the rest of the continent. This demand for Solar PV is supported not by consumer incentives but, rather, a fundamental business case built on energy pricing and a lack of energy security (and energy access for parts of the continent where energy utilities do not have significant population coverage), which will likely drive sustained market demand for Solar PV for the foreseeable future (Venter, 2022).

4. MATERIALS USED IN SOLAR PV

Solar PV installations rely on a steady stream of readily available, competitively priced input materials. The main materials in each of these technologies are shown in Table 1.

Table 1: Materials for Solar PV

MATERIALS FOR SOLAR PV	
Concrete	Essential for system support structures for Solar PV.
Steel	Steel and stainless steel are used in the manufacturing of several components, including system support structures for Solar PV.
Plastic	Polymers are used in Solar PV. The ethylene vinyl acetate polymer material holds the largest share in PV cell encapsulation. Polymers prevent humidity, dust, corrosion.
Glass	Used for substrates and module encapsulation in Solar PV.
Aluminium	Aluminium is used in Solar PV for module frames, racking and supports.
Copper	Copper is used for wiring, cabling, earthing, inverters, transformers, PV cell ribbons.
Iron	Besides iron, minor and base metals such as nickel, molybdenum, manganese and chromium are used in steel production.
Chromium	
Manganese	
Molybedium	
Nickel	
Zinc	
Silicon	By weight, c-Si PV panels typically contain about 5% silicon (solar cells), 1% copper (interconnectors), and less than 0.1% silver and other metals.
Cadmium	Used in other Solar PV technologies, which are generally seen as more efficient but currently have a very small share of the global market.
Gallium	
Indium	
Selenium	
Tellurium	

Source: Adapted from Carrara et al, 2020; Manufacturing Circle, 2022; International Energy Agency, 2021.

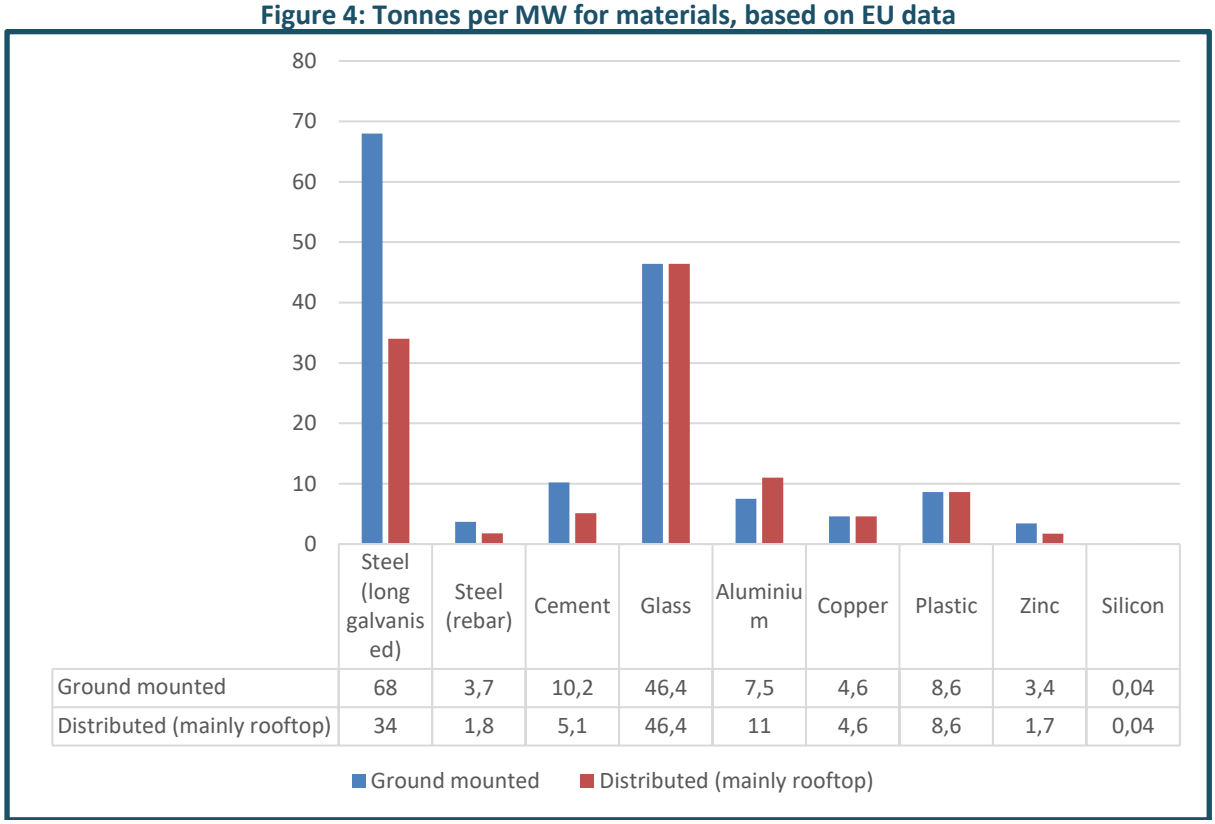
The availability of structural and technology specific minerals for RE requires a local mining industry or the imports of these minerals. Of note for Solar PV is that, while South Africa does possess iron ore deposits and various steel making capabilities, it does not have bauxite, which is necessary to make aluminium and this has to be imported. Furthermore, locally produced silicon is not of a quality that can readily be used in Solar PV. Local zinc production is, however, being increased.

Annexure C contains more detail on South Africa's mineral production and estimated reserve capacity.

4.1 Estimated demand for key materials for Solar PV South Africa

Figure 4 indicates the tonnes per MW required of each material for Solar PV including for utility scale/ ground mounted and distributed scale/rooftop mounted. This calculation of material needs is based on 90% mono or multi-crystalline silicon panel with 10% thin film, and on the experience in the European Union. (Thin film solar panels are not currently manufactured in South Africa).

Figure 4: Tonnes per MW for materials, based on EU data



	Steel (long galvanised)	Steel (rebar)	Cement	Glass	Aluminium	Copper	Plastic	Zinc	Silicon
Ground mounted	68	3,7	10,2	46,4	7,5	4,6	8,6	3,4	0,04
Distributed (mainly rooftop)	34	1,8	5,1	46,4	11	4,6	8,6	1,7	0,04

Source: Adapted from Manufacturing Circle, 2022. Based on Carrara et al, 2020.

Ground-mounted systems require about double the galvanised steel and reinforcing steel bars as is required by distributed generation. While not evident in the dataset used for Figure 4, distributed Solar PV systems can also require significantly more copper than utility-scale projects, as they rely on micro-inverters or string inverters and not centralised inverters. Other mineral intensities are similar between utility-scale and distributed applications (International Energy Agency, 2021).

Many of the main materials used in Solar PV manufacturing are available in South Africa but are not price competitive relative to imported materials. A second challenge is the limited availability of specific capabilities (such as extrusion capabilities) necessary for specific component manufacturing (Manufacturing Circle, 2022).

Globally, silicon, silver and copper are the three materials that are forecast to be in high demand for global PV expansion to 2040. These materials are also those for which there is a threat of supply shortages, with global supply chains already under pressure. There is also a risk of low profitability for firms if the market is too volatile or returns are too low with increasing costs.

With the increasing demand for commodities to produce Solar PV components and the costs of these commodities rising, there is scope and increasing interest in recycling Solar PV metals. Current global recycling rates of copper, aluminium, chromium, zinc, cobalt and REEs are, however, low (International Energy Agency, 2022b).

Global recycling of Solar PV

As Solar PV installations and equipment reach end-of-life, the quantity of waste is expected to grow significantly. In 2019, the world generated an estimated 18 000 tonnes of Solar PV panel waste and by 2050, PV panel waste could increase to 10 million tonnes annually (Tetra Tech ES. and Circularity Edge, 2021).

Solar PV and battery reuse and recycling have health risks. Problems associated with improper disposal of waste PV panels can include leaching of heavy metals such as lead. The European Union has a regulation – known as the WEEE Directive – that has banned electronic products, including PV panels, from being landfilled. In response, one research initiative, the Full Recovery End of Life Photovoltaic project, takes in 3 500 metric tonnes of PV panels annually. The process recovers silicon and other metals by heating the panels in a furnace; and an acid dissolving step and filtration then recover silicon. Other metals are recovered via electrolysis. Up to 93% of materials can be recovered from used PV panels. Most of the remaining material is plastic, which is burned in the furnace to provide additional energy. A number of other global initiatives are also underway to safely and affordably extract materials from panels (Tetra Tech ES. and Circularity Edge, 2021).

There is no publicly available information in South Africa on what happens to Solar PV components when they reach their end-of-life. The 2021 Amendments to the Regulations and Notices regarding Extended Producer Responsibility within the Waste Act require companies to take responsibility for packaging the waste of their products but this does not currently extend to components in Solar PV (although it does cover electronic products, such as appliances, household portable batteries, lighting, information technology and communication equipment, and consumables, such as printer cartridges.) There appears to be a domestic policy gap on the repair, reuse and recycling of Solar PV and other renewables' waste, which must be addressed.

5. IMPORTS AND EXPORTS OF SOLAR PV COMPONENTS

Around the world, increasing trade measures are being put in place in parts of the Solar PV supply chain: the number of antidumping, countervailing and import duties has increased from only one import tax to 16 duties and import taxes, with eight additional policies under consideration in 2022 (International Energy Agency, 2022b).South Africa has its own challenges with copper theft and is considering scrap metal export bans in an attempt to address this (Cronje, 2022).

As South Africa exports relatively little to the global Solar PV market, and is reliant on imports of key components, these shifts in global trade duties and general supply chain challenges are a risk to the rapid roll-out of local Solar PV. To better understand South Africa's trade of Solar PV components, import and export data for the main components of Solar PV have been generated from the International Trade Centre (ITC) Trade Map services, based on the selection of products in these industries characteristic of climate mitigation (Wind, 2009).

For the purposes of the graphs that follow, the detailed products have been collapsed into a few component categories to best (relate to the main componentry, with certain key subcomponents highlighted. Many of these characteristic products are not exclusively used in Solar PV and have broader industrial applications.

Figure 5: Exports of Solar PV characteristic products, 2010 to 2021, in USD thousands

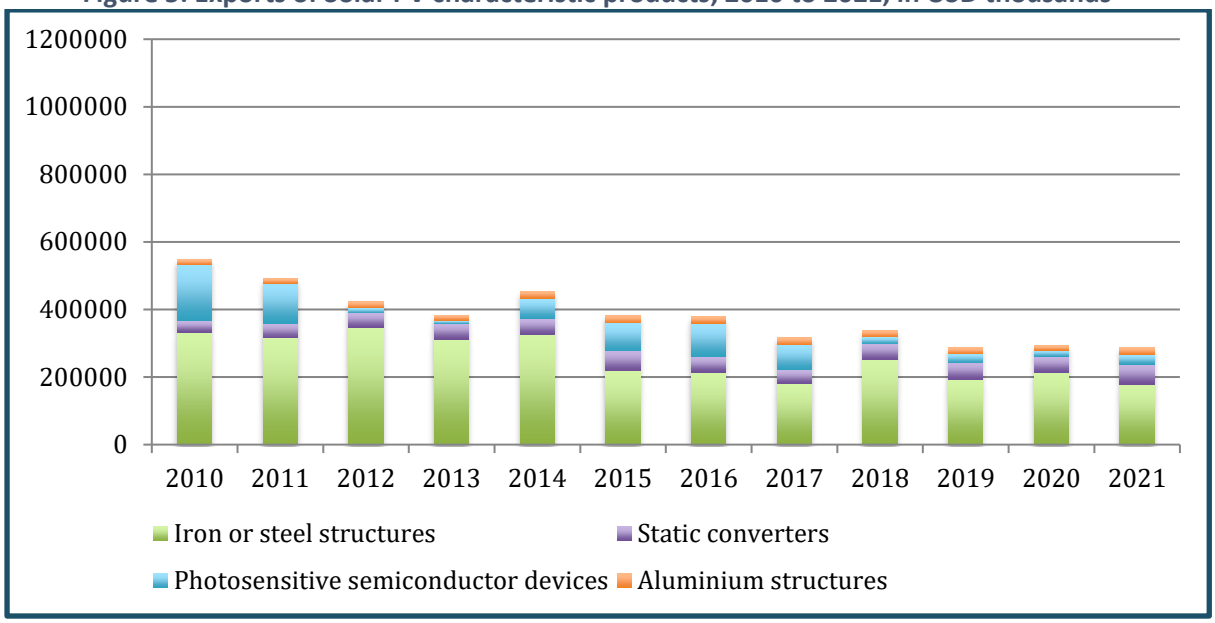
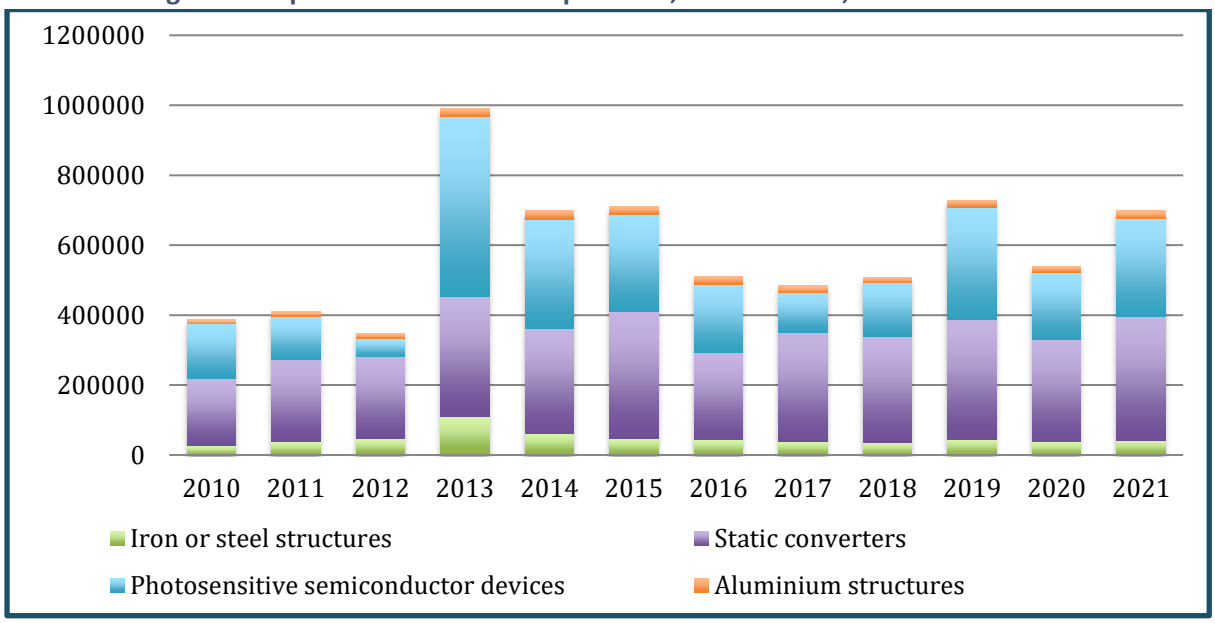


Figure 6: Import Data for Solar PV products, 2010 to 2021, in USD thousands



Sources: ITC calculations based on South African Revenue Services (SARS) statistics since January, 2015 and ITC calculations based on UN Comtrade statistics until January 2015 using Harmonised System Codes contained within Wind, I. HS Codes and the Renewable Energy Sector.

South Africa exports fewer Solar PV characteristic products than it imports. Exports have also declined over time from about US$500 million per annum in 2010 to just under US$300 million in 2021. Imports of Solar PV characteristic products have been volatile over the last 12 years: these had a total value of just under US$400 million in 2010, 2011 and 2012, but grew to a high of just under US$1 billion in 2013, in line with the construction of REI4P projects. They have since declined again, due to delays in the REI4P programme.

The main product driving the import volatility is “photosensitive semiconductor devices” (PV modules), which grew from about US’$150 million in 2010 to just over US$500 million in 2013. “Static converters” (Inverters) are also a major category of imports but have shown less volatility in import demand and value.

The largest export product category of Solar PV is "iron or steel structures", which relates to the mounting structures (but quite likely also has many other non-RE applications). The value of exports of "iron or steel struct ures" has, however, declined from about US$330 million in 2010 to US$177 million in 2021. So too have exports of "photosensitive semiconductor devices". "Aluminium structures" and "iron or steel structures" comprised a small share of the value of imported Solar PV characteristic goods between 2010 and 2021.

6. CONCLUDING COMMENTS

Electricity market reform is likely to drive a significant increase in Solar PV projects across the country, in turn increasing demand for components and services. Yet, the opening (in 2012) and subsequent closure of local manufacturing facilities by global inverter firms indicates the critical need for reliable and sustained demand as well as policy certainty in this space (the dtic, 2021).

Currently there are relatively few local firms involved in manufacturing for Solar PV. These firms require further industrial development support to grow and expand employment. In particular:

- For inverters, the feasibility should be investigated of an *investment into a laboratory* that can provide EU standards certification as well as test imported smaller inverters (such as string inverters) for the local SSEG market against South African electricity quality. This would support manufacturers of both large and small inverters to compete with imported products.
- Developing improved *professionalisation* of installers is also an important focus area with strong growth in SSEG. PV GreenCard is doing work to professionalise installers but more can be done. For small rooftop Solar PV consumers, the landscape is difficult to understand and price differentials between suppliers are significant. What constitutes value for money for a reasonable technology product is not clear to consumers. The process and experience of getting quotes for and installing rooftop solar can be confusing and lack necessary assurances. More can be done to upskill, professionalise and support this rapidly growing part of the Solar PV SSEG market.
- Access to *concessional finance* should be provided to support the growth of local small engineering businesses that manufacture inverters and are already well established and exporting to the rest of the continent (and further afield).
- Small firms are cautious about participating in the REI4P as component suppliers. The terms of the REI4P programme, the conditionality, financial guarantees, OEM requirements and relationships, long lead times in the delivery of projects, and downward price pressures, make it a difficult space for small firms to participate in, despite local designation regulations[6]. While the SSEG market provides opportunities for these smaller firms, local manufacturers need to be supported to participate as Tier 2 suppliers to REI4P. Development finance institutions can also help with providing guarantees, cash flow relief, and other financial products and concessions to manufacturers. OEMs should also be encouraged to consider investing in local manufacturing facilities. For this, policy certainty will be key (the dtic, 2021).
- *Training programmes* are required to create skills to take advantage of employment opportunities for technicians, electricians, and similar for inverter manufacturing, assembly, installation, servicing and repair. In the case of utility-scale installations, with capital-intensive technology, the correct skills levels are essential to responsibly and safely operate the specialised equipment.

[6] The Department of Trade, Industry and Competition's automotive industry development programme has been referenced by academics and a local manufacturing firm as a potential model for significantly upscaling the local RE manufacturing industry. That is, that a major industrial programme, with both import taxes and industry incentives, could support component manufacture for RE industries (Malengret, 2022).

These global skills tend to be in great demand and South Africa needs to compete with other global destinations for them. While the country does have a certain skills base, there is a need to upskill and professionalise local staff to fulfil technical roles in the value chain. This may require pairing foreign skills with local graduates or with other staff for on-the-job training.

- The dominance in the market of imported goods challenges local firms. *Measures to manage imports* and support local suppliers should be carefully considered. This includes further local designation requirements for inverters (both assembly and manufacture) and monitoring of the application of existing local requirements, import taxes, local standards, and similar.
- The locally manufactured steel and aluminium inputs for customised mounting structures are not cheaper in South Africa than imports. Here, the import parity pricing works against the use of local billets in mounting structures and frames. Tied to this, while some capabilities exist among the steel and aluminium firms to produce the correctly specified products, these capabilities have been under pressure in the manufacturing sector. For manufacturing to use local billets, the lack of price competitiveness and limited capabilities needs to be addressed.
- An initiative to deal with Solar PV componentry waste is required. This could address opportunities for reuse and recycling of critical materials, as well as reduce material waste flows and health risks associated with Solar PV.
- In terms of import replacement potential, there is an opportunity to grow local manufacturing capabilities in "photosensitive semiconductor devices" (PV modules) and "static converters" (inverters) as these are the two largest categories in value of imported Solar PV characteristic goods. Local demand from existing and prospective manufacturers should be supported adequately.

Over the upcoming months as the draft South African Renewable Energy Masterplan[7] is finalised and implemented, there will be space to explore these and other industrial development support measures. These must be appropriately aligned to industry conditions and potential and, with that, decent work creation.

While South African renewable energy stakeholders focus on building local capabilities, there are a range of geopolitical and macroeconomic challenges beyond domestic borders that are likely to impact the work and potential. This presents challenges and opportunities. For manufacturers supplying private Solar PV projects that are outside of REI4P, there appears to be considerable opportunity for expansion, not just in South Africa but also into the rest of the continent (and, indeed, South African firms are already doing so). At the same time, the International Energy Agency has indicated the difficulty in forecasting beyond 2023: Solar PV is facing higher investment costs as a result of elevated commodity prices resulting from Russia's Ukraine invasion; complications and delays with power purchase agreements especially in the European Union; and rising interest rat are raising costs of capital for renewable developers (International Energy Agency, 2022a).

Plans for future Solar PV manufacturing in South Africa will need to consider these global shifts and future volatility in global renewable energy markets in addition to local conditions and industry potential.

[7] It should be noted that the draft SAREM of March 2022 does not take into account the recent opening up of the market to private generators. The process and draft masterplan predate that development.

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Annexure A: SAPVIA membership list, May 2022

CONSULTING	
Energy Infrastructure Management Services (Pty) Ltd	Zutari (Pty) Ltd
Eskom	UL VS South Africa
DNV South Africa (Pty) Ltd	ED Systems
Element Consulting Engineers	IBC Solar
Estudios Energeticos Consultores	PVinsight, Nelson Mandela University
GREEN Solar Academy Pty Ltd	Resolution Circle (Pty) Ltd
Hamsa Consulting Engineers	Council for Scientific and Industrial Research (CSIR)
Jager (Pty) Ltd	
CUSTOMER	
CPV Power Plant No. 1 (RF) (Pty) Ltd	
DEVELOPER	
Cennergi Pty Ltd	Leano Construction Solutions
Genesis Eco-Energy (Pty) Ltd	Mabe-Tinyi Business Enterprise
Globeleq South African Management Services (Pty) Ltd	Mulilo Renewable Project Development
juwi Renewable Energies	Solar Saver
Mainstream Renewable Power, SA (Pty) Ltd	SolarAfrica Energy (Pty) Ltd
Biotherm	Solek
Bright Light Solar	SOLINK
Firefly Investments 253 (Rf) (Pty) Ltd	Total Solar Southern Africa
Iberdrola Renewables South Africa	WKN Windcurrent
Kabi Solar (Pty) Ltd	Inpower
Meridian Energy	Yellow Door Energy
Gentricity	Averge Technologies (Pty) ltd
Amperion Energy	Adzam Solar (Pty) Ltd
Aces Africa (Pty) Ltd	Voltalia
Trenditrade 21 (Pty) Ltd/ Nashua	Sphandile Trading Enterprise (Pty) ltd
EPC	
ACDC Dynamics	New Southern Energy
Distributed Power Africa (Pty) Ltd.	oneSolar
Ellies Electronics (Pty) Ltd	Romano Solar (Pty) Ltd
Enel Green Power RSA (Pty) Ltd	Shared Energy Management
MBHE Group (Pty) Ltd	Sinetech Energy (Pty) Ltd
Scatec Solar	Solar MD (Pty)Ltd
Barloworld Power	Sosimple Energy
Eco Trades Solar Power	Soventix
EDF Renewables	Sustainable Power Solutions
Emergent Energy	Synergy Energy Solutions Pty (Ltd)
Emesco Holdings (Pty) Ltd	Tagex Energy (Pty) Ltd
ENERTRAG South Africa	Terra Firma Solutions

EP Solar	Wetility
GC Solar	IMPOWER Solar Energy & Storage
Gransolar (Pty) Ltd	LTM Energy (Pty) Ltd
Granville Energy	Motla Consulting Engineers (Pty) Ltd
IB Vogt SA (PTY) Ltd	NESA Power
FINANCE	
African Infrastructure Investment Managers (AIIM)	candi Solar
Nedbank	Reatile Group (Pty) Ltd
Broadreach Capital	
INSTALLER	
Bafenyienergy	Ohmega Renewable Energy (Pty) Ltd
Cedar Solar	One Energy Group (Pty) Ltd
Earth Care Solar	Oryx Renewables (Pty) Ltd.
Elite Energy Solutions	Premium Solar
EnergyOn South Africa Pty Ltd	Renen Energy Solutions
GENERGY	Sensible Solar
Mike's Electrical an Solar	Sinetech (Pty) Ltd
Solardelight (Pty) Ltd	
MANUFACTURER/ SUPPLIER	
Canadian Solar Inc	Hulamin Extrusions
Hellermann Tyton (Pty) Ltd	Ingeteam Pty Ltd
Huawei Technologies Africa (Pty) Ltd	Qinisa Steel Solutions (Pty) Ltd
JinkoSolar (Pty) Ltd	Renewsys South Africa (PTY) Ltd
SMA Solar Technology South Africa	Rubicon Renewables & Automation
SOLA	SARETEC - South African Renewable Energy Technology Centre
DEHN Africa (Pty) Ltd	Segen Solar (Pty) Ltd
Fibon Energy	Specialised Battery Systems
GoodWe Europe GmbH	STI Norland
OTHER BALANCE OF SERVICE	
DevRani Consult	GAC Laser International Logistics
Solarvest	

Source: www.sapvia.co.za

Annexure B: GreenCape list of Solar PV firms in its Designated Local Content database, May 2022

DESIGNATED SECTOR, COMPONENT OR PRODUCT	SUPPLIER NAME	MANUFACTURER/ WHOLESALER
DC Combiner Boxes	Valsa	Wholesaler
DC Combiner Boxes	Sinetech	Wholesaler
DC Combiner Boxes	SegenSolar	Wholesaler
DC Combiner Boxes	IBC Solar	Wholesaler
Inverter	SMA Solar Technologies	Wholesaler
Inverter	Allsolar	Wholesaler
Inverter	ACDC Dynamics	Wholesaler
Inverter	3W Power (AEG Power Solutions)	Manufacturer
Inverter	Goodwe	Wholesaler
Inverter	ZRW Mechanika	Wholesaler
Inverter	SMA Solar Technologies	Wholesaler
Inverter	Microcare	Manufacturer
Inverter	MLT Iinverters	Manufacturer
Inverter	Valsa	Wholesaler
Inverter	Huawei Technologies Africa	Wholesaler
Inverter	IBC Solar	Wholesaler
Inverter	Sinetech	Wholesaler
Inverter	Enertronica Santerno South Africa	Manufacturer
Laminated PV Modules	SegenSolar	Wholesaler
Laminated PV Modules	ArtSolar	Manufacturer
Laminated PV Modules	Seraphim	Manufacturer
Laminated PV Modules	Canadian Solar	Wholesaler
Laminated PV Modules	JinkoSolar	Wholesaler
Laminated PV Modules	IBC Solar	Wholesaler
Laminated PV Modules	Valsa	Wholesaler
Laminated PV Modules	Renewsys South Africa	Wholesaler
Laminated PV Modules	Rubicon Renewables & Automation	Wholesaler
Laminated PV Modules	SegenSolar	Wholesaler
Laminated PV Modules	SetSolar	Wholesaler
Laminated PV Modules	Sinetech	Wholesaler
Laminated PV Modules	Suntech	Wholesaler
Laminated PV Modules	IBC Solar	Wholesaler

Module Frame	DEHN	Wholesaler
Mounting Structure	Pia Solar	Wholesaler
Mounting Structure	Valsa	Wholesaler
Mounting Structure	KD Solar	Manufacturer
Mounting Structure	K2 Systems	Wholesaler
Mounting Structure	Sinetech	Wholesaler
Mounting Structure	Solarframe	Manufacturer
Mounting Structure	STI Norland	Wholesaler
Mounting Structure	Lumax Energy	Wholesaler
Mounting Structure	Caracal Engineering	Manufacturer

Annexure C: Mining commodities in South Africa – Key data

COMMODITY	USE IN RE	SUBSTITUTES	SOUTH AFRICAN RESERVES	EMPLOYMENT IN SOUTH AFRICA (2021)	WORLD RANKING OF RESERVES – NO	SHARE	SALES VALUE (R '000S)	COMMODITY PRICE CHANGE 2020/2021 (USD)
Iron ore	For steel – extensive use in structures	No substitute	640 Mt (Million tonnes)	21 247	11	0.8%	120 781 852	38.5% per dry metric tonne
Manganese	Used in steel	No satisfactory substitutes	520 Mt	13 290	1	40%	37 098 932	n/d
Rare Earth Elements (REEs)	Various, including new PV module technologies	Substitutes often less effective	790 000 Mt	Not available	11	0.7%	n/d	n/d
Chrome Ore/Chromium	Essential in steel production, robotics	No substitute in stainless steel	200 000 Mt	18 599	1	35%	21 974 540	n/d
Lithium	*Essential for low-carbon energy but South Africa has no noteworthy reserves*							
Bauxite	*Essential for aluminium production but South Africa has no reserves*							
PGMs	Often used as a catalyst	Palladium	63 000 Kilotonnes (kt)	171 568	1	91.3%	346 525 529	23.5% per ounce (platinum)
NON-FERROUS MINERALS								
Copper	Essential in solar PV production, cabling	Aluminium, titanium and steel	11 000 kt	17 953 in total, including lead	11	1%	2 745 652	51% per metric tonne
Cobalt	Energy storage, UV economy	98% if cobalt is a byproduct of nickel and copper mining	n/d		n/d	n/d	170 527	n/d
Nickel	Mobility, drones, storage	Low-nickel, duplex, or ultrahigh-chromium stainless steels, nickel-free specialty steels, titanium alloys	n/d					
Zinc	Solar panels and electric cars; coats wind turbines to stop corrosion	Aluminium alloys, cadmium, paint, and plastic coating, magnesium base alloys	14 000 kt		n/d	n/d	7 084 935	32.5% per metric tonne

Source: Minerals Council, 2022.