INSIGHTS INTO THE WIND ENERGY 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
IRP	Integrated Resource Plan
IPP	Independent Power Producer
ITC	International Trade Centre
kV	Kilovolt
kVA	Kilovolt-Amperes
OEM	Original Equipment Manufacturer
MVA	Megvolt-Amperes
MW	Megawatt
NERSA	National Energy Regulator of South Africa
SAREM	South African Renewable Energy Masterplan
PMG	Permanent Magnet Generators
PV	Photovoltaic
RE	Renewable Energy
REEs	Rare Earth Elements
REI4P	Renewable Energy Independent Power Producers Procurement Programme
USD	United States Dollars
SANAS	South African National Accreditation System
SAWEA	South African Wind Energy Association
VC	Value chain

1. INTRODUCTION

The South African Integrated Resource Plan (IRP) 2019 provides that by 2030 the electricity generation mix is to comprise of 17 742 megawatts (MW) or 21% wind energy (IPP Office, 2022). By the end of December 2021, 3 357MW of wind energy had been procured in Bid Windows 1 to 4 of the Renewable Energy Independent Power Producers Procurement Programme (REI4P) through 34 projects. Thirty-one of these plants were operational by December 2021 (IPP Office, 2021). 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). Approximately 5 000 new large wind turbines, with 15 000 blades, will be needed by 2030 to meet the 14 000MW of new capacity indicated in the IRP 2019 (Cronje, 2019). (Cronje, 2019). South Africa's wind plants are big – the average project size for the 34 wind IPPs is 98.7MW.

Outside of the REI4P, electricity market reforms recently announced, promulgated or gazetted for comment should result in an increase in large private and municipal projects. These include amendments to the Electricity Regulation Act No. 4 of 2006 which, on 12 August 2021, increased 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 188MW before that. Most of the projects are based on Solar Photovoltaic (PV) technology (at 86% of total reported generation capacity). Only 11% is Wind Energy (Montmasson-Clair, 2022). With the recent (July 2022) Presidential Electricity Plan announcement of the total removal of the licensing threshold for embedded generation, these numbers might well increase dramatically (Ramaphosa, 2022).

Overall, the push for more electricity generation, particularly renewable energy (RE) generation, is likely to result in a significant increase in Wind Energy projects across the country. This in turn will drive demand for components and services needed for the development and operations of wind plants. Given this context, and to add to the existing body of knowledge on the manufacturing value chain (VC) for Wind Energy, this report provides focused insights on:

- Tower manufacturing;
- Materials for Wind Energy; and
- Imports and exports of Wind Energy components.

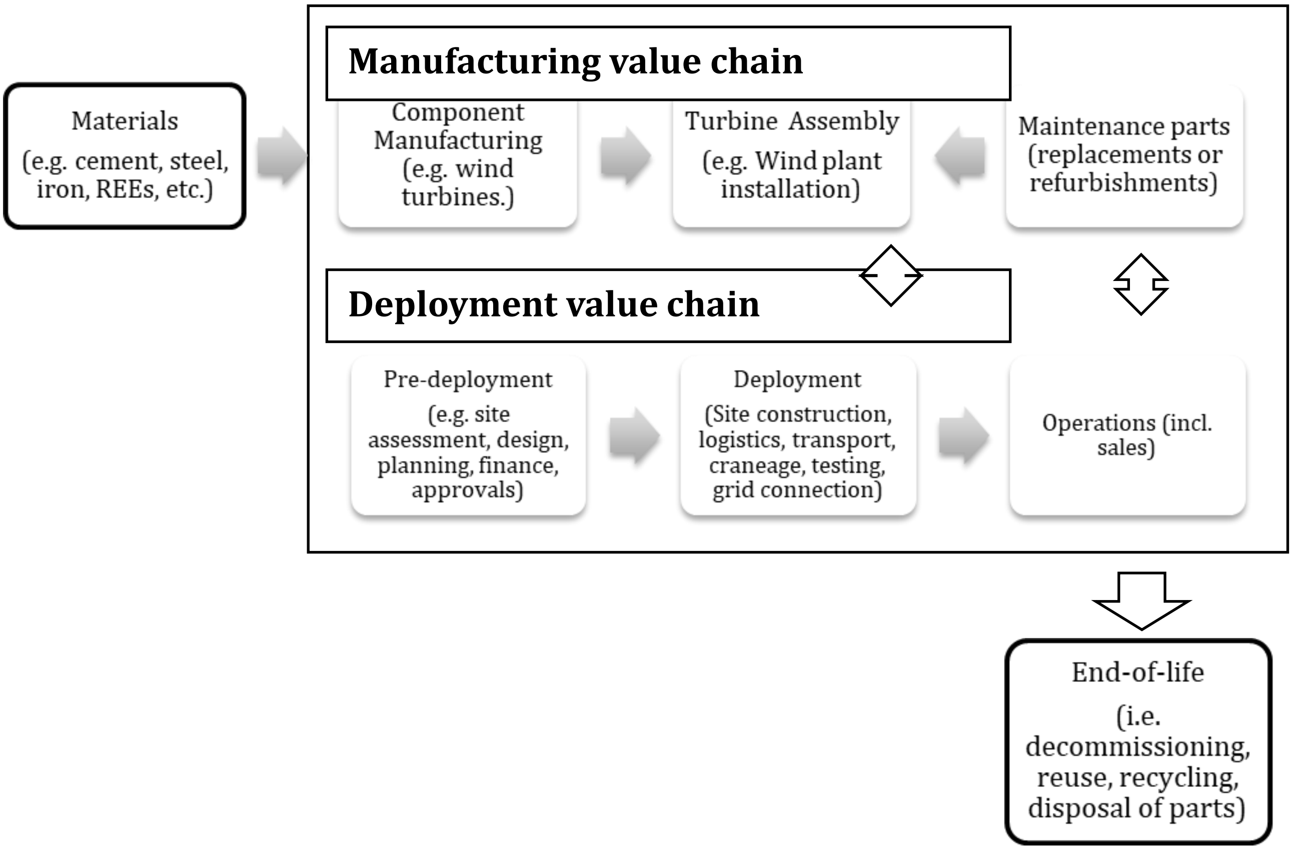
2. BACKGROUND: DESCRIPTION OF THE VALUE CHAIN

The VC can be depicted two ways:

- In terms of *project deployment phases*: from conception to delivery, operations, and 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 VCs and how they interact, including the backward linkages to materials for the manufacturing chain and the forward linkages to end-of-life for RE materials. This 'end of life' is when the operational phase for the infrastructure has come to an end. While there is some time before the 'end of life' phase for South Africa's wind plants, it is nonetheless worthwhile to consider the circularity opportunities that exist, as well as some of the waste-related challenges from Wind Energy.

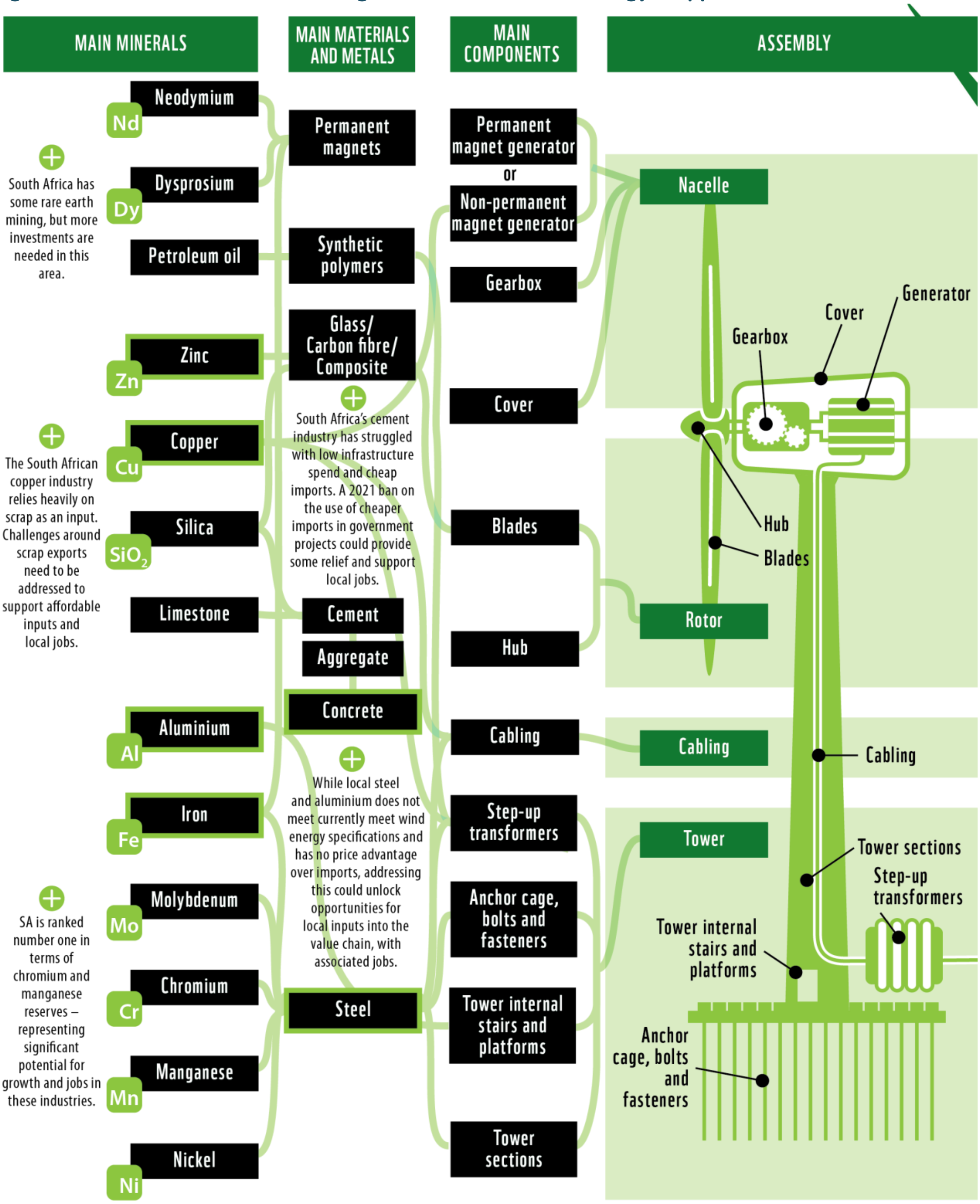
Figure 1: Value chains

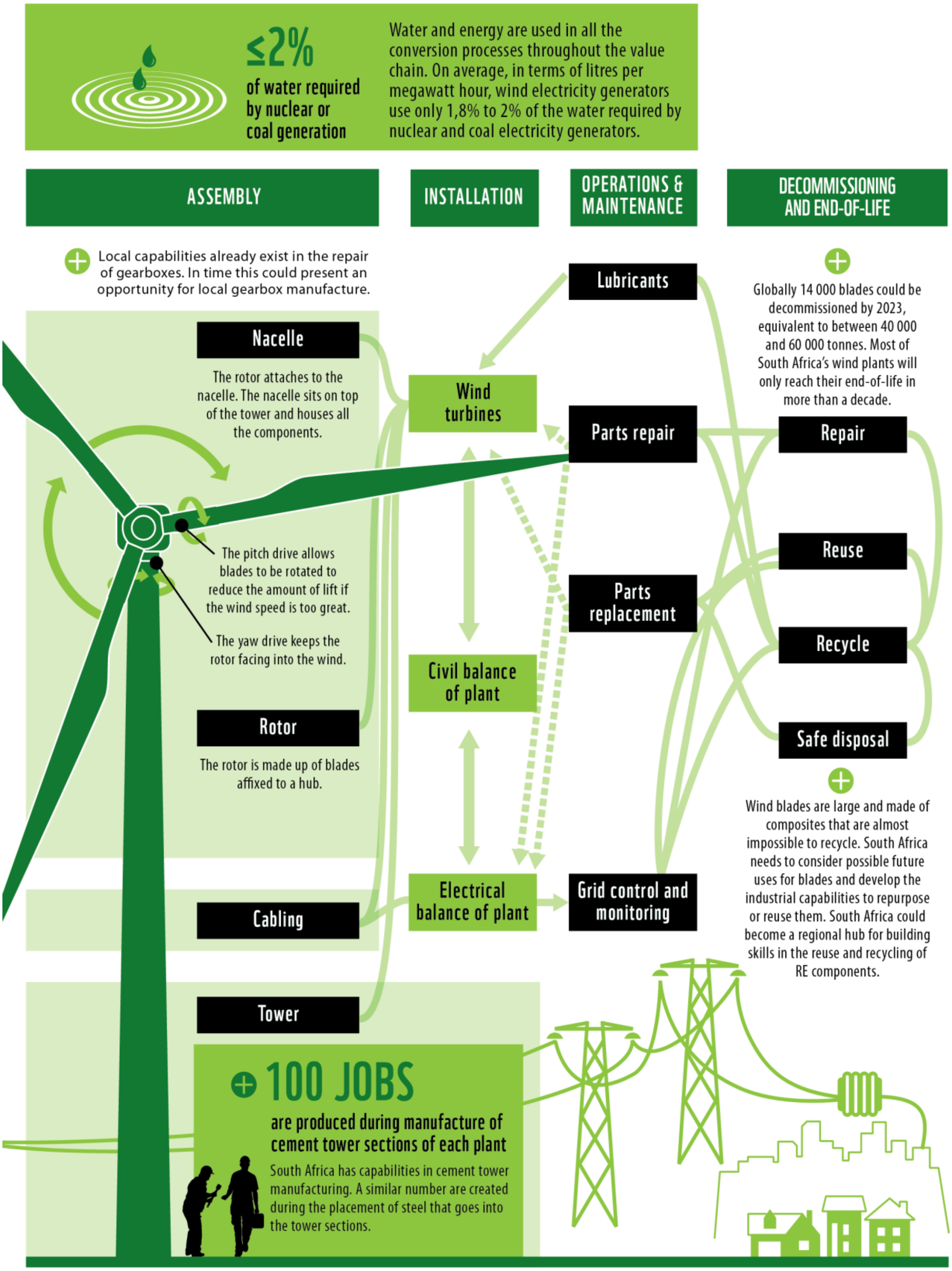


Source: Author

A detailed view of the manufacturing VC for Wind Energy, from materials to end-of-life, is provided in Figure 2.

Figure 2: Materials and manufacturing value chain for Wind Energy – Opportunities for South Africa





Source: Adapted from Author, designed by WWF South Africa

Firms involved in large and utility-scale Wind Energy projects include investors and financiers, project developers, Original Equipment Manufacturers (OEMs), power producers, consultants, Engineering, Procurement and Construction (EPC) firms, component and subcomponent wholesalers and manufacturers of components, among others. There is no single source of firms active in Wind Energy value chains. The main industry association, the South African Wind Energy Association (SAWEA), lists data on its members, which cover many categories of activities (although manufacturers are under-represented). The full SAWEA list of members across membership categories, as of May 2022, is provided in Annexure A.

While this report focuses on manufacturing inputs, there also exists an array of services required by the Wind Energy market; many are required in the project deployment phase. Here, large 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, and civil works. The project example below describes the array of firms involved in the development of a wind farm.

Wind farm project example

Jeffreys Bay Wind Farm started commercial operations in July 2014. The **investors** in the project were Globeleq (owner and operator), Mainstream Renewable Power, Thebe Investment Corporation, Old Mutual Life Assurance Company (South Africa), engineering firms Enzani Technologies and Usizo Engineering, and a local community trust, the Amandla Omoya Trust. The **financiers** included a syndicate of lenders led by ABSA and Barclays, and included the Development Bank of Southern Africa, certain local institutional investors, Globeleq and its consortium partners.

The project site covers an area of 3 700ha, spanning across eight farms, of which the turbine components cover 4% of the land while the remaining areas are used for cultivation. The work primarily involved the construction of the wind turbine foundations and installation of the turbines using two cranes. Other work included improvements to the access roads for transportation of the turbines to the site, construction of a substation and an operations and maintenance facility, and cabling for the substation and electrical collection system. Transportation of the wind turbines from the Port of Ngqura to the project site started in July 2013 and was completed in February 2014, covering a total distance of 110 000km.

Each of the 60 Siemens SWT 2.3MW wind turbines is 80m tall with blades measuring 49m long. Each rotor has a diameter of 101m and weighs 60t, and each nacelle weighs 82t. The tubular steel towers weigh 162t, and the average rotation of the blades is between six and 16 revolutions per minute. Clean energy generated from the wind farm is fed to the neighbouring 132kV Eskom grid line.

Siemens, who supplied the turbines, is also responsible for maintaining them for an initial period of 10 years. The civil and electrical works were carried out by the consortium of Murray & Roberts Construction and Consolidated Power Projects. They also oversaw the construction of the new substation, roads, foundations and civil buildings, including medium and high-voltage installations.

Up to 60 pad-mounted transformer kiosks, each integrating a customised 2.7MVA 33kV/690V distribution transformer, a 33kV gas-insulated ring main unit and low voltage equipment, were supplied by ACTOM MV Switchgear. The transportation contractor for the project was deugro, while Ingozi Management provided occupational health and safety services.

Construction started in December 2012. The first turbine was erected in September 2013, while 60 turbines were set in place in March 2014 and initial operations started in April of the same year. At its peak, approximately 600 to 700 people were involved in the construction, 45% of which were from the local communities in the Kouga Municipality. In addition, it created up to 11 permanent jobs.

Source: Adapted from Power Technology, 2014.

Project developers of private Wind Energy projects have fewer contractual requirements than those within the REI4P, including in terms of local content stipulations. They are also able to negotiate offtake agreements with clients that are not subject to the pricing regime of the REI4P. The recent announcements on electricity market reforms, which allow private players to wheel and sell back into the grid, are likely to drive strong growth in this market. It is, however, by no means certain that this will translate into greater procurement of components that are locally manufactured.

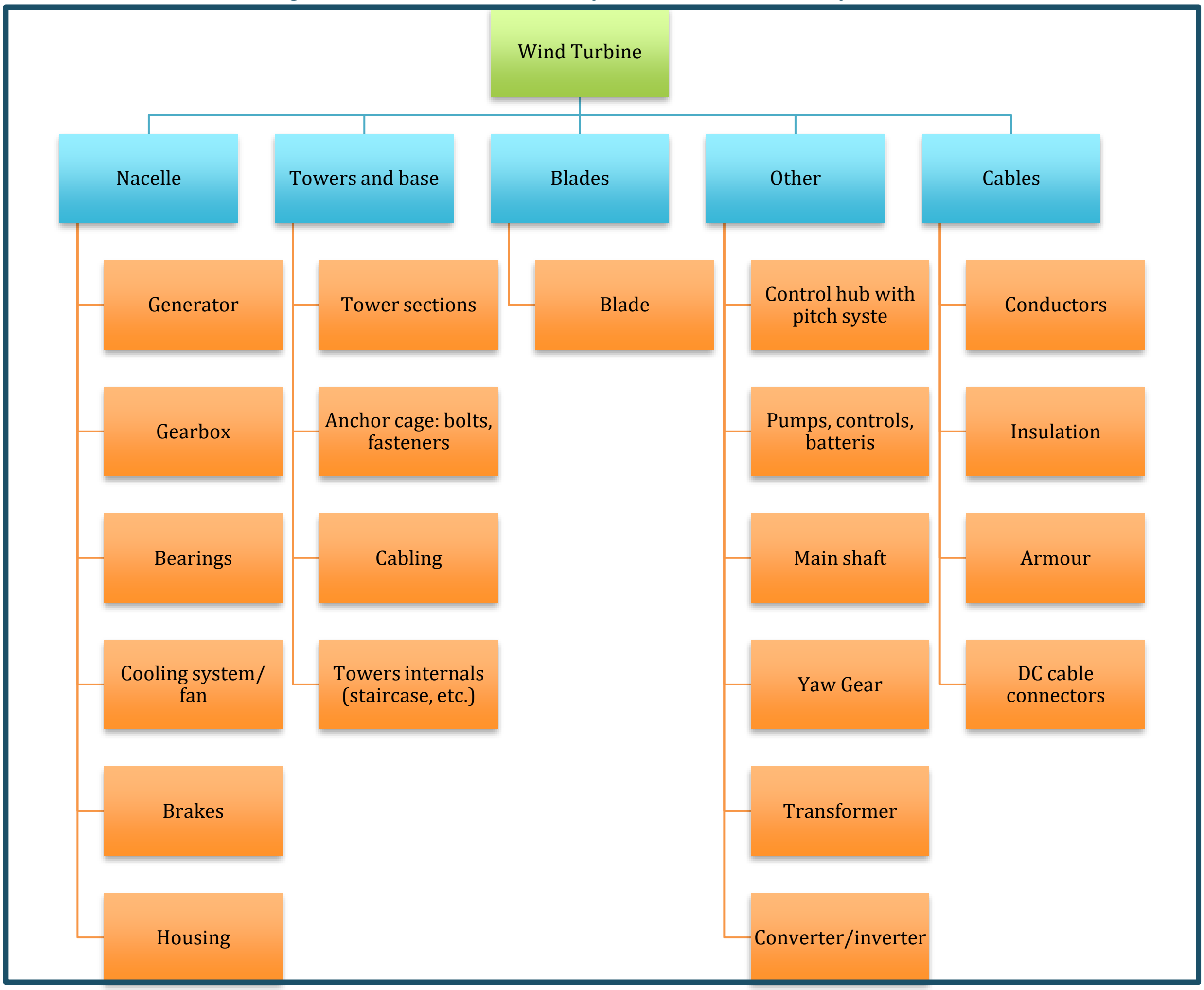
3. WIND ENERGY COMPONENTS AND SUBCOMPONENTS

Wind Energy generation only occurs for utility- and large-scale projects in South Africa. Unlike Solar Photovoltaics, it has little uptake in the distributed generation market.

The main components in a wind turbine are the wind towers, blades and nacelle. Wind Energy generators also require 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 capital expenditure that do not include the wind turbine components and assembly. The BOP is generally broken down into logistics and installation, civil and electrical services, and components. South Africa's existing capacity in civil engineering, construction, and electrical services has meant most of these BOP elements have readily been supplied by local companies. An exception is the parts of the electrical BOP, for which much is imported.

Figure 3 indicates the main components and subcomponents of a wind turbine.

Figure 3: Wind turbine components and subcomponents



Source: DMRE, the dtic and DSI, 2022.

Local content expenditure reported for wind Independent Power Producers (IPPs) (that have all started and/or concluded construction) amounts to R24.5 billion of total project spend of R52.1 billion, or 47% of the project value for wind projects to date. These locally procured elements are, however, largely in the BOP, particularly transport, erection, foundation as well as in the tower itself (IPP Office, 2022). While the South African Renewable energy Masterplan (SAREM) indicates that "South Africa has a solid base for manufacturing key components – a strong steel and cement industry for towers and electro-technical expertise" (DMRE, the dtic and DSI, 2022: 14), there are relatively few local component and subcomponent manufacturers in the Wind Energy industry.

According to data from the IPP Office, based on Bid Window 4, the BOP constitutes about 34% of total construction costs and the nacelle sub-assemblies, about 40% of the plant capital cost. OEMs typically procure all the main wind turbine componentry in line with their particular specifications and needs. A relatively small group of global OEMs dominate the global wind market. In 2019, four manufacturers accounted for more than half, at 55%, of the machines deployed: Denmark's Vestas, Spain's Siemens Gamesa, China's Goldwind, and General Electric of the United States (BloombergNET, 2020).

The main drivers of centralised procurement and choices of suppliers by the OEMs relate to the scale of the procurement programme, the price, and warranties, and trusted relationships with suppliers.

Of the key components:

- The generator and gearbox are the largest cost share, at 22% and 9% of total capital expenditure respectively" (DMRE, the dtic and DSI, 2022). While wind turbine generators are not currently manufactured in South Africa, some are repaired locally (by Cape Armature Winders in the Winelands).
- Blades are manufactured outside of the country and imported.
- South African capacity exists for manufacturing of the nacelle cover and machining of the main frame but is not currently utilised in the Wind Energy VC.
- The base of the tower with its anchor cage and fasteners is locally procured, and the towers are locally built of either steel (imported) or cement. Most of the tower "internals", such as ladders, are not manufactured locally. Tower "internals"', as a category, include the ladders, platforms and cabling within the tower. The ladders and platforms are usually made of aluminium, but the correct specifications are not readily available in South Africa.
- Parts of the electrical BOP are locally manufactured but the MV cable, LV/MV transformer and switchgear are not (the dtic, 2021). Aberdare[1] and CBI African Cables are local alternating current cable manufacturers.
- Transformers are manufactured locally and supplied to Wind Energy plants.

[1] Aberdare is a large local operation that was bought by Chinese cable manufacturer Hengtong in 2016. Hengtong has a presence in 120 countries. Aberdare employs 1 500 people.

Local transformer manufacturers

Zest WEG operates two transformer manufacturing facilities in South Africa. For instance, Zest WEG has delivered a locally manufactured main power transformer to a wind farm project near Swellendam in the Western Cape. The 45MVA (megavolt amperes) transformer was designed to receive 33kV (kilovolts) from the wind turbines and step this up to 132 kV for the main power grid. The transformer was built at Zest WEG's Heidelberg facility and, following comprehensive testing at the facility's laboratory in 2019, the transformer was delivered to site and assembled. Zest-WEG's engineers conducted full on-site testing of the unit, as well as cold commissioning (Zest, 2020).

ACTOM Power Transformers has designed a number of low-cost transformers for wind farms including 157 x 2 700kVA (kilovolt amperes) pad-mounted, oil-natural, air-natural transformers. Consolidated Power Projects, the electrical BOP contractor for the wind farms, Noupoort, Khobab and Loeriesfontein, ordered their transformers from ACTOM. ACTOM had previously also supplied the Kouga Wind farm project. Newer transformers also accommodate the load-break switch together with current limiting fuses inside the transformer tank by mounting them under oil, in place of the usual external arrangement as applied to package transformers. This reduces the cost. ACTOM is the largest manufacturer, solution provider, repairer and distributor of electro-mechanical equipment in Africa and has 40 distribution outlets throughout Southern Africa. This includes the supply of electrical equipment, services and BOP to renewable energy projects (ACTOM, 2015).

Powertech Transformers has over 60 years of experience in design, manufacturing, testing, installation and commissioning of a full range of power and distribution transformers. The Powertech Transformers Group consists of two transformer divisions, Power Transformers and Distribution Transformers, plus an insulation business. Recently, a services division has been started that focuses on service and maintenance, commissioning as well as condition assessment for any type or make of transformer. Powertech Transformers has a fully South African National Accreditation System accredited laboratory that offers analysis and testing of oil (Devex, n.d.).

SGB-SMIT POWER MATLA has a large power transformer factory in Pretoria West. This is one of the largest transformer manufacturing plants within the Southern Hemisphere and one of two large manufacturers within Sub-Saharan Africa. It produces 10MVA to 800MVA transformers with primary voltages of up to 420kV. The Distribution Transformer factory in Cape Town manufactures transformers from 16kVA to 5MVA. SGB-SMIT POWER MATLA manufactures generator step-up transformers which are installed in power utilities throughout South Africa. Voltages up to 800MVA 420kV are manufactured at the Pretoria factory, including for the solar power and wind energy plants. The Pretoria plant had a fire in 2021 (SGB-SMIT POWER MALTA, n.d.).

3.1 Spotlight on tower sections

The tower sections are enormous and heavy as they are made of either concrete or steel. This creates a competitive advantage for local firms that can produce towers close to site, as the cost of transport and logistics is significant (13% of the total cost for wind farms in REI4P Round 4 was transport) (DMRE, the dtic and DSI, 2022).

Tower manufacturers

There are three local tower section manufacturers: Concrete Units (based at Cape Town Airport Industria), the Copperton plant (in Copperton, Northern Cape) and GRI Towers (based in Atlantis, outside of Cape Town).

GRI Renewable Industries is a global company, with 16 factories in six countries. They produce wind towers from steel. The South African firm, GRI Towers South Africa, opened its factory in Atlantis in the Strategic Economic Zone in 2014. GRI has already produced a number of steel towers for REI4P projects in the country. The local firm has a production capacity of 150 wind towers/year – equivalent of 400MW in new wind farms/year. They are not functioning at full capacity, however. Although no formal data is available, it appears concrete towers are more in use in South Africa. This is not the case elsewhere in the world.

Concrete Units was established in 1987 and provides pre-cast concrete solutions in Cape Town and the Western Cape. Its products include bridge beams, supports for the dry-docking of ships, large diameter sewer pipes lined and sea wall defense units as well as more standardised precast products. Concrete Units has supplied concrete towers in two bid windows of the REI4P:

- In 2014, Windtechnic and Concrete Units were awarded a contract to manufacture 46 concrete wind towers for Acciona Windpower to use in a wind farm in Gouda in the Western Cape. The towers for the Gouda wind farm are 100m high and the turbine on top of each tower can generate 3MW. The farm can feed up to 138MW into the national grid. Each tower is made up of 17 precast concrete segments which are 20 metres long. The widest segment is six metres wide and the heaviest segment weighs 65 tons. The 782 segments required for the contract were cast in its Cape Town precast yard and were transported, by truck, to the Gouda wind farm. Gouda was the first wind farm in Africa where the towers were made from concrete rather than steel.
- In 2019, Concrete Units and Windtechnic were awarded a contract to supply 47 towers to Nordex Energy South Africa. The towers are used in a wind farm built at Roggeveld. The 799 tower segments required for the farm were cast by Concrete Units in its yard in Cape Town and trucked to the wind farm.

The Nordex/WBHO, Copperton concrete plant is the third concrete tower manufacturing operation in South Africa. It operates from a factory in Prieska, Northern Cape. This plant was built to supply concrete towers to the Copperton and Garob windfarms for Nordex, which received the contracts to install a total of 80AW125/3150 turbines for the two projects.

- Garob comprises 46 turbines and was announced as ready for commercial operations in December 2021 by Enel Green Power. Construction of the plant included the on-site building of concrete towers completed by local contractors, providing employment for about 511 people from the local community at peak of the construction phase of the project (Enel Green Power, 2021).
- Copperton comprises 34 turbines for the developer and independent power producer Elawan. Here cement tower manufacture includes delivery and installation as well as multi-year service contracts.

Stefanutti Stocks had a precast facility for concrete towers in Nxuba, Eastern Cape, but this has closed.

Employment and skills' development

GRI's 2021 integrated annual report indicated that 156 permanent staff are employed in South Africa, of which 11 are women. A further four "scholarship" staff were employed, also permanently (GRI, 2021).

At Concrete Unit's Cape Town factory, 100 people have been employed for each wind tower project over the 10 months of manufacturing. This has been in addition to the 20 full-time staff members at Concrete Units and indirect jobs in the supply chain, such as an additional 100 people employed by the steel contractor to place the reinforcing cage inside the concrete sections. Furthermore, erection of concrete towers is more labour intensive than it is for steel towers, requiring a number of people on site (Charl Coetzee, 2022).

Components and subcomponents

Actual site-based concrete tower parameters are established to determine the exact specifications of the material required for each plant and tower. Very high early strengths are needed in the concrete. This typically limits the kinds of aggregates that can be applied. PPC is Concrete Unit's main cement supplier from its closest sites[2]. There are however currently no PPC cement plants in the Northern Cape. Concrete Units outsources the readymix to a specialist firm, Megamix, to produce this for them to the correct specifications.

Abnormal load trucks are used to transport the concrete sections to site, with police escorts in certain instances. Erection is done on site by a separate team. Foreign skills are brought in to oversee the highly technical installation.

While Concrete Units manufactures the towers, other contracts go to a civil engineering contractor to cast the concrete bases and to an internals' supplier. Certain tower internals may be cast in the panel for the concrete tower and for this Concrete Units sources local companies to provide these parts. The price for internals that are produced locally can, however, be higher than the imported equivalent.

Concrete Units works directly with the OEMs, such as Nordex. Windtechnic Engineering, Concrete Unit's partner, provides quality engineers for the projects, as this requires specific skills. While Windtechnic has trained local people, the delays in the conclusion of the REI4P bid windows have meant certain local skills have been lost. Windtechnic has a suite of engineers; some are fulltime employees, others are local contracted in for projects (Charl Coetzee, 2022).

The reinforcing steel that reinforces the concrete panels has become much more expensive (70% increase in three years). About 15 000kg to 19 000kg of thin reinforcing steel are fixed each day of tower section construction, which has substantially increased manufacturing costs. Concrete Units' reinforcing supplier for the cutting and bending sources steel directly from ArcelorMittal. A specialist firm is contracted to correctly fix the reinforcing bars into the jigs, by hand. The price of diesel has also dramatically increased – this is needed for local transport. As cement is locally produced, it is not subject to significant price pressures at present.

According to its website, GRI Towers services in South Africa include: steel treatments, such as cutting and beveling; circular welding process; electrical components such as wiring, trays, fuses; internals, such as platforms, ladders, elevators, doors; surface treatments, such as metalising, blasting, and painting; and tower manufacture bending and welding (GRI, 2021). South Africa does not produce steel to the right specification for GRI and this is imported for the manufacturing of the tower parts. The current local content stipulations designate steel although wind towers themselves are not designated (DMRE, the dtic and DSI, 2022).

[2] In terms of imported cements, the recently introduced surcharges on imported cement will result in local firms providing cement. Imported cements can also be of an inferior quality.

Growth potential and barriers

The conclusion of contracts for the construction of wind farms forming part of Bid Window 5 of the South African REI4P is scheduled for 2022. Concrete Units hopes to provide towers for the Noupoort cluster working with Goldwind (a Chinese OEM) as there is an increased effort to source local inputs because of the local content stipulations. The new rounds involve fewer but taller towers (up to 124 metres from 100 metres in previous rounds) with different nacelles, which produce more energy per tower. Concrete Units also expects to be involved in building more towers for the wind farms from 2023 onwards, subject to delays in the REI4P being resolved.

Barriers to growth

In addition to the price of inputs (as indicated above), particularly for steel and diesel, delays in the REI4P bid windows have limited production and skills transfer, as well as investment in new plants. Transport permits for abnormal loads are also a problem, with delays experienced and slower permitting in the Western Cape than elsewhere (Charl Coetzee, 2022).

The slowness in approvals for permitting and licences for new cement plant development can also impede growth. Concrete Units is developing a new factory in Middelburg, Eastern Cape, for the manufacturing of concrete towers for the Noupoort cluster. It has taken almost a year to get the rezoning, water licence and environmental approvals in place.[3] Furthermore, performance guarantees required by suppliers are significant and, as a result, development delays present significant risks (Charl Coetzee, 2022).

4. MATERIALS USED IN WIND ENERGY

Wind Energy relies on a steady stream of readily available, competitively priced input materials. Wind plants are materials' intensive and the Bid Window 5 of the REI4P could require inputs amounting to:

- 80 000 –100 000 t (metric tonnes) of steel plates
- 4 000 tonnes of steel for anchor cages
- 6 500 tonnes of rebars for foundations
- 3 500 tonnes of structural bolts
- 640 000 litres of paint (locally manufactured)
- 200 tonnes of industrial gases (locally manufactured)
- 500 tonnes of internal aluminium platforms
- 36 800 metres of electrical cables and
- 240 000 metres of power cables (Mora, 2021).

The main materials needed for Wind energy plants are shown in Table 1.

[3] In this instance, the delays in the Bid Windows have worked in their favour as the new plant had time to get its approvals but, in general, REI4P contracts do not accommodate these sorts of delays in commissioning.

Table 1: Main materials used in Wind Energy

MATERIAL	USE
Concrete	Essential for foundations and tower sections in wind plants.
Steel	Steel and stainless steel are used in the manufacturing of several components, including the tower, nacelle, rotor and foundation.
Plastic	Polymers are used in the wind turbine and are additionally used together with aluminium, copper and steel in the production of cables for the plant.
Carbon-fire	Composite materials are primarily used in the construction of the blades, as well as the nacelle and hub cover. The main materials used in the blades are carbon fibre and woven glass fibres infused with epoxy resin; and the nacelle cover is made from fibreglass, which consists of woven glass fibres, polyethylene and styrene.
Aluminium	Aluminium is used in the turbine tower and nacelle. Aluminium is also used in the production of cables at the plant site.
Copper	Copper is predominantly used in the coil windings in the stator and rotor portions of the generator, in the high-voltage power cable conductors, transformer coils and earthing.
Iron	Besides iron, minor and base metals such as nickel, molybdenum, manganese and chromium are used in steel production. Aluminium, tin, zinc, tantalum and precious metals, in various amounts, are among the main constituents of electronic components for Wind Energy.
Chromium	
Manganese	
Molybedium	
Nickel	
Zinc	
Neodymium	An average permanent magnet in a wind generator contains 28.5% neodymium, 4.4 % dysprosium, 1% boron and 66 % iron. There is also some minor use of rare-earth elements in magnets within the turbine tower for attaching internal fixtures (Carter, 2021). Terbium is used in the permanent magnet of the turbine generator where it replaces dysprosium. Neodynium, Dysprosium and Terbium are viewed as having both high vulnerability and high supply risk (Jellicoe, 2019).
Praseofymium	
Terbium	
Dysprosium	

Source: Adapted from Carrara, et al., 2020; Manufacturing Circle, 2022; and IEA, 2022.

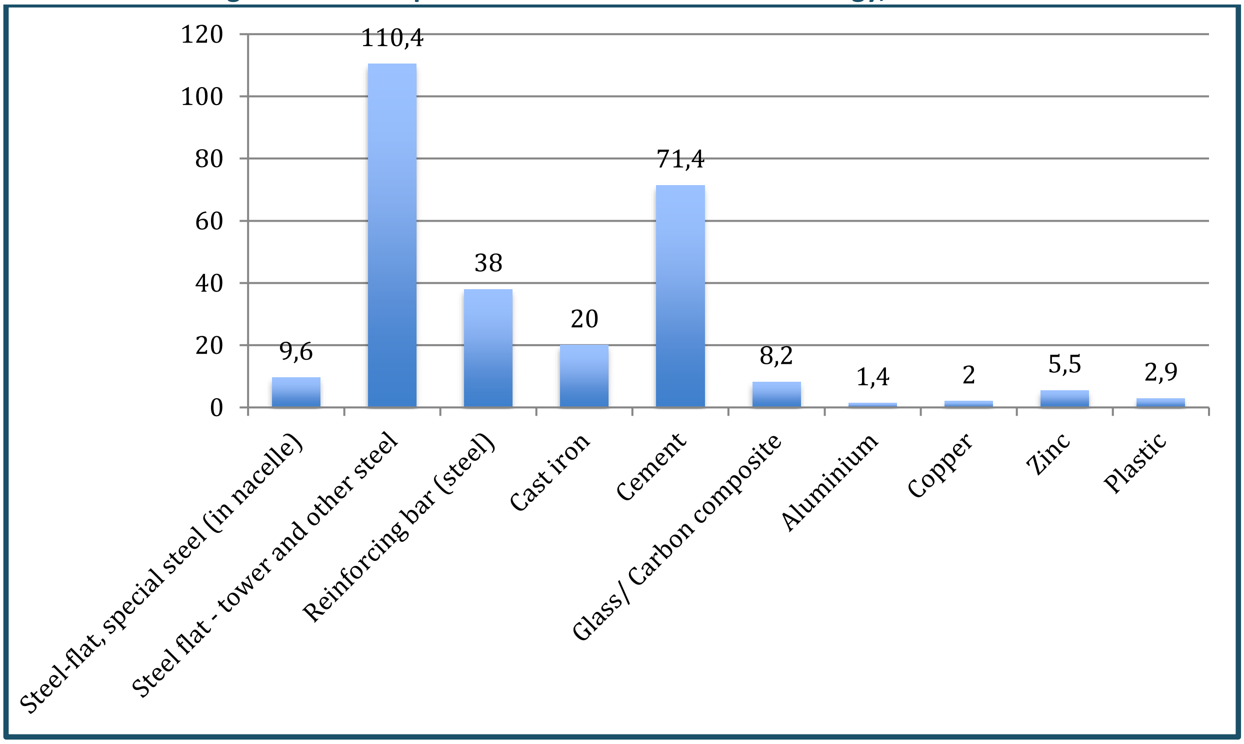
The availability of materials for Wind Energy requires a local mining and processing industry or the import of these materials. Of note for Wind Energy is that, while South Africa does possess iron ore deposits and various steel making capabilities, it does not have bauxite which is necessary to make aluminium. This is imported for local aluminium smelting to take place. South Africa does have marginal reserves of Rare Earth Elements (REE) but it is not clear how much is mined locally or makes its way into components made elsewhere in the world.

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

4.1. Estimated demand for key materials for Wind Energy in South Africa

Figure 6 indicates the average tonnes per MW required of each material for Wind Energy. Wind Energy materials' use is calculated based on steel towers, with turbines assumed to be an average of 4MW per turbine, as estimates are based on European Union data. In terms of actual practice, for cement towers in South Africa, it has been estimated that a 3 MW industrial wind turbine in South Africa uses 1 200 tonnes of reinforced concrete, or 400 tonnes per MW (Gulati, 2018), far more than the approximately 70 tonnes indicated in Figure 4.

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



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

While steel requirements for South Africa are overstated in Figure 4 (as the data is based on steel towers), iron ore, cast iron and different forms of steel[4] are nonetheless a large share of required materials even when cement towers are used, as forms of steel are used throughout the turbines. Most of the steel and aluminium requirements for use in Wind Energy manufacturing are available in South Africa but are not deemed price competitive relative to imported materials and may not be available in the right form, where specific extrusion capabilities do not exist (Manufacturing Circle, 2022).

Copper is forecast to be in high demand for renewable energy expansion to 2040 and South Africa will continue to compete for supplies of this material. Current global recycling rates of copper, aluminium, chromium, zinc, cobalt and REEs are low and there appears to be significant scope to recover more of these materials (IEA, 2022). South Africa is exploring further scrap metal bans to try to limit copper theft, among other challenges with the local supply of this material. The box below looks at some of the global challenges and recent developments in the recycling and reuse of Wind Energy components.

[4] The terminology here includes that reinforced steel is also known as 'rebar' and that iron-case is cast iron - a group of iron-carbon alloys with a carbon content of more than 2 to 4 percent.

Recycling and reuse of Wind Energy components

WindEurope estimates that around 14 000 blades could be decommissioned by 2023, equivalent to between 40 000 and 60 000 tonnes (Tetra Tech ES and Circularity Edge, 2021) Wind turbines are particularly difficult to dispose of as they are very large, making them unsuitable for landfills and costly to transport. Wind turbines also comprise of composite of glass fiber and epoxy or another thermoset resin. The cross-linked polymers cannot be melted down and recycled. Other wind turbine components, including the tower, gearbox and generator, are more readily recyclable. A number of initiatives are underway to address these challenges.

Examples of recycling of Wind Energy

- Global Fiberglass Solutions plans to build a recycling centre in Sweetwater, USA, the self-proclaimed wind energy capital of the world. They have developed a method to break down blades and press them into pellets and fibre boards to be used for flooring and walls (Bomgardner and Scott, 2018).

New kinds of blades

- In September 2021, Siemens Gamesa unveiled the world's first wind turbine blade that can be recycled at the end of its lifespan. The RecyclableBlades are made with a new type of resin, which Siemens says can be efficiently separated at the end of the blade's working life, enabling the materials to be reused in new applications. The first 81-metre-long blades have already been manufactured for piloting.
- A French specialty chemical firm, Arkema, has made a single blade using a composite of glass fibre and methacrylate resin, which unlike epoxy, can be melted and recycled (Bomgardner and Scott, 2018).

Examples of reuse of Wind Energy components

- In Europe, wind turbines may be reused as wind blades in other countries in the region once their initial project lifetime is complete.
- Bridges can be constructed using decommissioned wind turbine blades: The Irish Blade Bridge is being built by Re-Wind Network, an interdisciplinary team from the Georgia Institute of Technology, University College Cork, Queen's University Belfast and City University of New York. It aims to repurpose old wind turbine blades rather than sending them to landfill or incineration. Re-Wind has already created a turbine blade bike shelter in the Danish city of Aalborg and the researchers have also compiled an entire catalogue full of other proposals. Future applications are likely to include turbine-blade farming equipment, bus shelters and noise barriers (HDI, 2022).

In South Africa, the new Extended Producer Responsibility Act does not yet address Wind Energy waste streams and more work is required to regulate the safe reuse, recycling and disposal of RE component materials.

5. IMPORTS AND EXPORTS OF WIND ENERGY CHARACTERISTIC PRODUCTS

Import and export data for the main components of onshore wind 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 that relate to the main componentry, with certain key subcomponents. Certain of the products have broader industrial application and are also used in other industries.

Figure 5: Main exports of onshore wind characteristics products, 2010 to 2021, in USD thousands

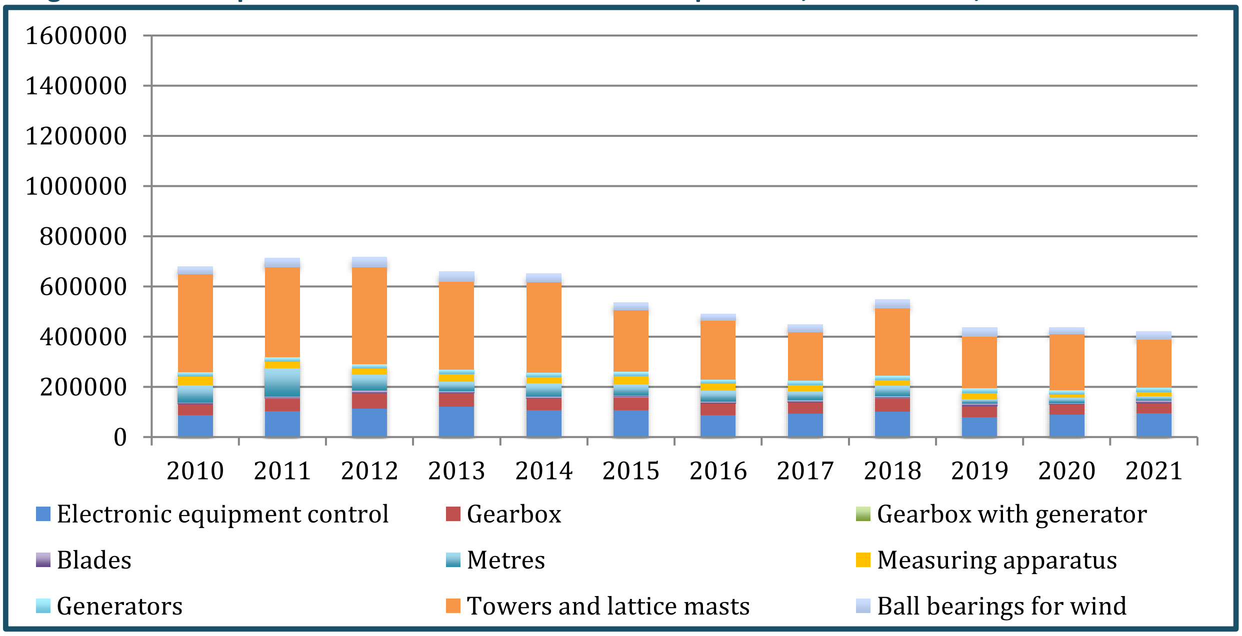
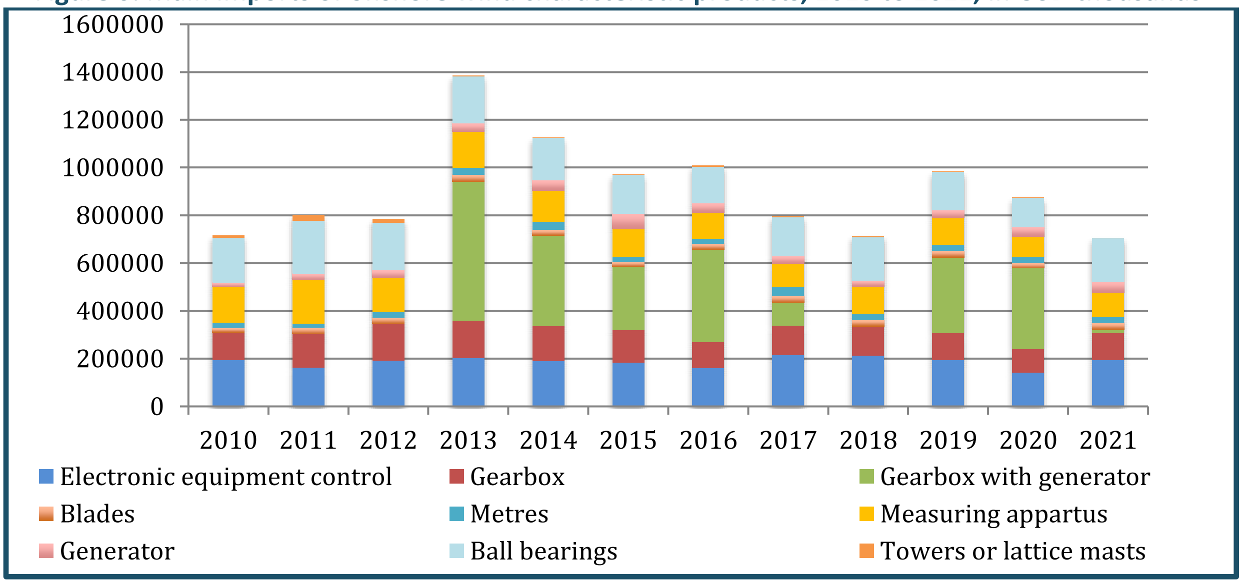


Figure 6: Main imports of onshore wind characteristic products, 2010 to 2021, in USD thousands



Sources: ITC calculations based on South African Revenue Services 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 Sector1. ICTSD Programme on Trade and Environment.

South Africa exports far less than it imports of Wind Energy characteristic products. Exports have declined from about US$700 million between 2012 to just over US$400 million in 2021. The largest export product under the Wind Energy category is "towers and lattice masts".[5] However, the value of exports in this product declined from about US$388 million to US$188 million between 2010 and 2021.

Imports of onshore wind characteristic products have been volatile over the 12 years. The total import value was lowest at US$700 million in 2010 with a similar total value in 2021. The highest import value was about US$1.4 billion in 2013. The main product driving the import volatility appears to be "gearboxes with generators", which grew from a value of less than US$1 million in 2010 to US$580 million in 2013. Other sizeable categories of imports of Wind Energy characteristic products are "ball bearings", "measuring apparatus", "gearboxes" and "electronic equipment control".

[5] This product is mainly used to hold the antennas for communications and television broadcasting.

6. CONCLUDING COMMENTS

Electricity market reform is likely to drive an increase in Wind Energy projects across the country. This will in turn increase demand for components and services. Wind Energy does not have a small-scale embedded market, so the potential for rapid off-take relates to the REI4P and large private projects. But despite this possible rapid growth in demand for components, there are currently relatively few local firms involved in manufacturing for Wind Energy. For the main components in a wind turbine, only the towers, transformers and some cabling are made in South Africa.

The local firms participating in the componentry require further industrial development support to grow and expand employment. In particular, fixing the impediments to local manufacturing for utility-scale (and highly competitive and technology dependent) projects will require measures to address barriers, including the lack of local competitively priced input materials. The stop-start nature of the REI4P bid windows to date has constrained local manufacturing potential but the recent opening up of the market means that demand for Wind Energy is no longer solely reliant on that programme.

Further considerations to improve the opportunities for growth in local manufacturing of components for Wind Energy include:

- Participation in the REI4P programme for local manufacturers is challenged by the conditionality, financial guarantees, OEM requirements and relationships, and long lead times in the delivery of projects, among other factors. This make supplying to the REI4P difficult for small firms despite local designation regulations. There accordingly exists an opportunity to configure industrial support and address the REI4P design to better support local manufacturers. This may include improved access to carefully structured concessional finance.
- In terms of tower manufacturing, local precast concrete is at a distinct advantage over steel towers. A local precast concrete facility, close to a cluster of wind plants, has significantly fewer transport and logistics' costs; it also meets the local content requirements. The development of toll manufacturing facilities that could produce for several OEMs is an opportunity that could be further explored.
- For the local manufacturing of tower internals, like ladders, the correct specifications of aluminium need to be extruded locally. The same is true for steel: the correct specifications for steel are required and, while certain capabilities do exist in South Africa, steel suitable for the steel towers is not available. Opportunities need to be explored to produce both the correct steel and aluminium products in South Africa.
- While there may be an opportunity to assemble nacelles locally (Creamer, 2020), moving beyond assembly into the manufacture of nacelle parts and blades will take an investment in skills, capabilities and partnerships with leading OEMs. As one South African firm is already involved in fixing gearboxes, there may be an opportunity to move into the manufacturing of gearboxes or sub-componentry. Gearboxes with generators are a major category of imports for Wind Energy in terms of its value. If local capabilities exist, this is an area for which import substitution could be investigated, in conjunction with partnerships with OEMs to procure these locally made inputs.
- Other manufactured products which are not unique to RE industries, like fasteners, for example, should also be locally sourced. While not the focus of this research, it is crucial that industry associations representing firms manufacturing these more "generic" products used in wind plants are also made aware of the potential that RE markets hold, and that their member firms are supported to respond to this opportunity. This is particularly the case when existing, traditional markets might be under pressure (such as in the supply to coal plants, for example).

- Manufacturing for utility-scale Wind Energy requires a high level of skills. This necessitates specific technical training and development. The correct skills levels are also required in operations – to responsibly and safely operate the specialised equipment. These global skills tend to be in great demand for which South Africa needs to compete. There is a need to upskill and professionalise local staff to fulfil technical roles in the value chain. This may require special training and accreditation, and the pairing of foreign skills with local graduates or staff for on-the-job training.
- An initiative to deal with Wind Energy componentry waste should be investigated. This could address opportunities for the reuse and recycling of the blades and other parts as well as the extraction of critical materials. An organisation like the Council for Scientific and Industrial Research might be an appropriate partner for such an initiative.

All measures considered to support local industry participation must be appropriately aligned to industry conditions and potential and, with that, decent work creation. Over the upcoming months as the draft South African Renewable Energy Masterplan[6] is finalised and implemented, there will be space to explore the recommendations above and other industrial development support measures.

While South African RE stakeholders focus on building local capabilities, a range of geopolitical and macroeconomic challenges beyond our borders are likely to impact the work and potential. This presents challenges and opportunities. The International Energy Agency has indicated the difficulty in forecasting beyond 2023: Wind Energy and Solar Photovoltaics are facing higher investment costs as a result of elevated commodity prices resulting from Russia's invasion of Ukraine and permitting delays in various first-quarter auction volumes. In addition, gas price increases are complicating power purchase agreements, especially in the European Union, while rising interest rates are raising the costs of capital for renewable energy developers (IEA, 2022).

Plans for future Wind Energy 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.

[6] It should be noted that SAREM does not take into the account the recent opening up of the market to private generators. The process and draft masterplan predate the President's announcement of July 2022.

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Annexure A: SAWEA membership list, May 2022

CONSTRUCTION, INSTALLATION AND GRID CONNECTIONS	
Element Consulting Engineers	Noupoort Wind Farm (RF) (Pty) Ltd
Kangnas Wind Farm (RF) (Pty) Ltd.	South Africa Mainstream Renewable Power Perdekraal East (Pty) Ltd
Khobab Wind Farm (RF) (Pty) Ltd	Umoja Rope Access (Pty) Ltd
Loeriesfontein 2 Wind Farm (RF) (PTY) Ltd	Worley
CONSULTANCY, PROFESSIONAL SERVICES/RESEARCH	
3E	Fasken
3Energy Renewables (Pty) Ltd	GEO-NET South Africa (Pty) Ltd
Alon Meyerov	GeoWIND
American Clean Power Association	Harmattan Renewables (Pty) Ltd
Arcus Consultancy Services Ltd	Inlexso (Pty) Ltd
ArcVera Renewables	Obelisk Group
Arup (Pty) Ltd	Raymond Takuba
Bophelo Impilo Development Centre	SAICA Enterprise Development (Pty) Ltd
CDQ Group	South African Renewable Energy Technology Centre (SARETEC) (CPUT)
Council for Scientific and Industrial Research (CSIR)	SP-Wind (Pty) Ltd
DNV	UL
ED Platform	VoltaConsult
ENSafrica	Zutari
DEVELOPERS	
ABO Wind Renewable Energies (Pty) Ltd.	Longyuan South Africa Renewables (Pty) Ltd
African Clean Energy Developments	Marubeni Middle-East & Africa Power Ltd
Atlantic Renewable Energy Partners (Pty) Ltd	Mulilo Renewable Project Developments
BTE Renewables	REDCap
EIMS Africa	Rosatom Central and Southern Africa
EnergyTEAM (SA) member of FEAG	South Africa Mainstream Renewable Power Developments (Pty) Ltd
G7 Renewable Energies (Pty) Ltd	Voltalia
Infinity Power Holding	Windlab Developments South Africa (Pty) Ltd
WKN-Windcurrent SA (Pty) Ltd	
FINANCIAL SERVICES	
Actis	Rand Merchant Bank
AIIM	
IPP	
Aurora Wind Power	Noblesfontein Wind Farm
Dorper Wind Farm	Red Rocket
ENGIE Southern Africa (Pty) Ltd	Rubicept (RF) (Pty) Ltd
Iberdrola Renewables South Africa (Pty) Ltd	Scatec
Kouga Wind Farm (RF) (Pty) Ltd	
MANUFACTURER	
Goldwind Africa (Pty) Ltd	GRI Wind Steel South Africa (Pty) Ltd
Nordex Energy South Africa (Pty) Ltd	Resolux Africa (Pty) Ltd
BFG Africa (Pty) Ltd	Ver-Chem (Pty) Ltd
OPERATIONS AND MAINTENANCE	
AID Renewables	Globeleq South Africa

Bureau Veritas South Africa	juwi Renewable Energies
Cennergi (Pty) Ltd	Tritec Sintered Products (Pty) Ltd
EDF Renewables	TUV Rheinland Inspection Services (Pty) Ltd
Enel Green Power RSA (Pty) Ltd	
OTHER	
Life College Trust	Savannah Environmental
ArcellorMittal	Sika South Africa (Pty) Ltd
Eskom	Valentino Adams
Adcorp BLU	GreenCape
Johnson Cranes	South African Independent Power Producers Association (SAIPPA)
TRANSPORT/ LOGISTICS	
GAC Laser International Logistics	Grant Cromhout
OEM	
General Electric South Africa (Pty) Ltd	Wind-Energy ENERCON South Africa (Pty) Ltd
Siemens Gamesa Renewable Energy (Pty) Ltd	ZEST WEG Group
Vestas Southern Africa (Pty) Ltd	

Annexure B: 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: Adapted from Minerals Council, 2022