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Aligning Renewable Energy Value Chains and Innovation Systems to Build South Africa's Manufacturing Economy

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Introduction

This report has been prepared as one input to multiple streams looking broadly at the topic of how innovation-led industrialisation can be improved or accelerated in South Africa, with the project's main research question being "what challenges and what opportunities exist for innovation-led industrialisation in South Africa?"

The focus of the report is the role of production systems and logistics in innovation-led industrialisation. More specifically, we consider how to apply innovation within broader structures of global value chains as an agent of change for the development of South Africa's manufacturing sector. In other words, our interpretation of "the use of production systems and logistics in innovation-led industrialisation" is the application of novel products and processes to strengthening the interlinkages between systems or sites of production with their respective supply chains.

In this introductory section, we briefly review the concept of (global) value chains, and the link between research, development and innovation (RDI), competitiveness and value chains.

Defining (Global) Value Chains as an Analytical Framework

A (manufacturing) value chain is a concept used to describe the series of activities that a company performs to deliver a product or service to customers, starting from the raw materials and ending with the delivery of the final product to the customer (Kaplinsky and Morris, 2001). It "examines the job descriptions, technologies, standards, regulations, products, processes, and markets in specific industries and places, thus providing a holistic view of global industries both from the top down and the bottom up." (Gereffi and Lee, 2016; Gereffi and Fernandez-Stark, 2011)

The value chain consists of primary and support activities. Primary activities are those that directly contribute to the creation of a product or service and include activities such as inbound logistics (receiving and storing raw materials), conversion operations (transforming raw materials into finished products), outbound logistics (delivering finished products to customers), marketing and sales (promoting and selling products), and customer service (providing after-sales support).

Support activities are those that support the primary activities and include activities such as procurement (sourcing raw materials and other resources or intermediate products), technology development (developing new products or processes), human resource management (recruiting, training, and retaining employees), and infrastructure (managing the company's physical and technological infrastructure).

The value chain concept is useful in three respects (Gereffi, Humphrey and Sturgeon, 2005). Firstly, it correctly identifies and emphasises the importance of efficient integration as the basis for manufacturing competitiveness. Secondly, it is useful in identifying opportunities for improving efficiency and creating competitive advantage by analyzing each stage of the process and the interlinkages. Thirdly, it identifies how lead firms exercise power over other linkages within the chain through requiring suppliers meet specified standards/protocols/regulations to enter and/or remain within the chain. By understanding the value chain, companies can better understand their cost structure and identify opportunities to optimize their operations, improve quality, and create more value for customers.

Global value chain (GVC) refers to the internationalization of the value chain concept, where the different stages of production and distribution of goods and services are located across different countries. In a global value chain, companies source inputs from multiple countries, often taking advantage of cost efficiencies or specialized expertise in different regions.

A global value chain includes not only the primary and support activities of a company, but also those of its suppliers, customers, and other partners. This means that companies must not only manage their own operations but also coordinate with their partners around the world to ensure that products are delivered on time, meet quality standards, and comply with local regulations.

The globalization of value chains has been facilitated by advances in transportation, communication, and information technologies (Kaplinsky, 2013). Companies can now easily source inputs from around the world, track inventory and shipments, and communicate with their partners in real-time.

However, global value chains also pose challenges for companies, such as managing risks associated with political instability, currency fluctuations, and supply chain disruptions. Companies must also navigate complex legal and regulatory environments in different countries and ensure compliance with social and environmental standards (Davis, Kaplinsky and Morris, 2018).

Overall, understanding the dynamics of global value chains is essential for companies to remain competitive in today's globalized economy. It requires a deep understanding of the local context and a collaborative approach to working with partners around the world.

Competitiveness and Value Chains

Competitiveness is also not only about how an individual firm operates within an economic system. It is also about the efficiency with which firms link together and cooperate horizontally and/or vertically, as noted in the extensive literature on clusters (horizontal cooperation) and value chains (vertical cooperation) (Gereffi and Lee, 2016).

In the case of clusters systemic competitiveness is achieved through collective efficiency. In respect of value chains – whether they be global, regional or domestic – this depends on achieving value chain alignment between the lead firms and their suppliers internalising these requirements/parameters to create the requisite systemic competitiveness. Value chains are based on lead firms exercising their power as governors of a chain and requiring their suppliers adhere to specific standards, regulations and protocols. Lead firms are hence drivers of standards and decisions down their supply chain to ensure the systemic competitiveness within the value chain (Kaplinsky and Morris, 2018).

Systemic competitiveness therefore depends on smooth alignment, referred to as 'value chain alignment', between the demands of lead firms and the capabilities of suppliers. The lead firms determine who their suppliers are, and how they operate within the chain. If they do not have the necessary competences, then they cannot enter the chain as a preferred supplier. If they cannot upgrade and ***innovate*** to meet the standards required, then they face the real danger of being excluded as a supplier (Kaplinsky, 2013).

Value Chains, Industrial and Innovation Policy

This issue of value chain alignment has important policy consequences for the state's potential role in both enhancing inter-firm linkages and also disrupting these linkages, the latter in order to facilitate localisation.

Box 1. Key elements of localisation in a value chain driven world

All developing countries seek localisation in some form or other as a public good because they seek to expand the domestic industrial base, increase local value added activities, expand domestic revenue generation, grow the number of people gainfully employed, and upgrade local skill levels. In order to facilitate localisation the state in a developing country has to take into account the following: 1) Localisation refers to industrial activities being set up within the local economy. If multinational firms set up subsidiaries within the domestic economy then concomitantly this is localisation. 3) In a world dominated by global or regional value chains, government policy can intervene to create an enabling environment in order to facilitate localisation, but it has to work with the lead firms in doing so rather than trying to substitute for their value chain role. 4) Localisation has to add value and create employment within the domestic economy. Local agents who only import products do not contribute to localisation and build the local manufacturing base.

We offer four policy consequences:

It is clear that not all firms are equal within value chains. Hence policy makers ignore the power of lead firms in governing the value chain dynamics at their peril.

The dynamics that drive specific value chains have to be unpicked to identify the most appropriate entry points to support the expansion of local actors. There is no point in articulating policy interventions in linkages where foreign firms overwhelmingly competitively dominate.

In the renewable energy space, industrial policy has to be aligned with energy policy in order to take advantage of value chain alignment possibilities for localisation and innovation.

The advent of GVCs has created new opportunities for companies to ***innovate***, thereby improving their products and processes.

It is the final point that leads the remaining discussion of this chapter. Innovation is essential for companies to remain competitive in GVCs. Companies must continually innovate and improve their GVC processes to stay ahead of the competition and meet the evolving needs of customers.

Our work has focussed on three main areas where companies must innovation to participate competitively within GVCs.

Expertise and Knowledge Transfer

GVCs offer companies access to a wider range of inputs, expertise, and knowledge from different parts of the world. This enables them to innovate and develop new products or processes by combining different technologies or ideas from different regions. For example, a company based in the United States may develop a new product by sourcing components from China, software from India, and design expertise from Europe.

Collaboration and Partnerships

GVCs also create new opportunities for companies to collaborate with other partners in the value chain to share knowledge and expertise. For example, a company may work with suppliers to develop new materials or manufacturing techniques that reduce costs or improve product quality.

New Markets

GVCs create new opportunities for companies to access new markets and customers. This can be achieved by developing products that are tailored to local markets, or by adapting existing products to meet the needs of customers in different regions.

In summary, innovation and GVCs are mutually reinforcing, as companies that innovate can take advantage of the opportunities created by global markets, while companies that participate in GVCs are more likely to innovate by leveraging the expertise and knowledge available from different parts of the world. The question is "how can this mutual relationship be enhanced?" We deal with this question by exploring the GVCs of wind energy (Section 2) and solar[1] energy (Section 3), and then extracting some key learning points for the project (Section 4). In the final section, both sectors are discussed in terms of how innovation can contribute to South Africa's broader participation within GVCs.

The Wind Energy Value Chain

Overview

The wind value chain consists of the following key stages:

Resource Assessment: This stage involves the identification of suitable locations for wind farms based on factors such as wind speed, terrain, and environmental impact.

Development: This stage involves obtaining permits, securing financing, and designing the wind farm. This may also involve negotiating power purchase agreements with utility companies.

Manufacturing: This stage involves the production of wind turbines and components such as blades, towers, and generators.

Construction: This stage involves the installation of the wind turbines, transmission lines, and other infrastructure required for the wind farm to function.

Operations and Maintenance: This stage involves the ongoing monitoring and maintenance of the wind turbines to ensure they operate efficiently and effectively.

Energy Generation: This stage involves the production of electricity from the wind turbines and its delivery to the grid.

Distribution and Retail: This stage involves the distribution of the electricity to end-users through transmission and distribution networks, and the retailing of electricity to consumers.

[1] In this report, solar energy technology refers specifically to photovoltaics. Other forms of solar energy technologies such as concentrated solar power are not included. The terms solar and photovoltaics are used interchangeably.

Each stage of the wind value chain involves a wide range of suppliers, service providers, and stakeholders (see **Figure 1**). The value chain is complex and can involve many different companies and organizations working together to deliver wind energy to consumers.

Figure 1. Wind energy value chain

Wind Energy Value Chain in South Africa

The wind energy value chain in South Africa has been shaped, almost completely, by the country's Renewable Energy Independent Power Producers Procurement Programme (REI4P) (Walwyn and Brent, 2015). It is therefore necessary to firstly describe this programme. Thereafter, we discuss its implications for the wind energy value chain.

Renewable Energy Independent Power Producers Procurement Programme

The IPP/REI4P wind and solar process laid the foundation for the entire renewable energy market in South Africa. Without its precedents, all other segments would have been primarily dependent on imported components. It determined the general character of the entire renewable energy market in South Africa. Understanding its dynamics and maintaining its upward trajectory is therefore critical for any major drive towards localisation, whether on a national, provincial or municipal level.

The key dynamics driving these REI4P based GVCs are that: 1) their market differs from mass market consumer goods market dynamics, and 2) their lead firms are driven by overwhelming requirements to maintain system integration between companies across a variety of sectors in order to ensure systemic viability which then becomes a core competency driver. These public/private renewable energy markets are not characterised by a classic competitive market found in private sector commercial dealings where buyers and consumers compete to achieve differential price rates in order to buy, sell and purchase a product in a competitive terrain which can potentially shift at any given moment as the competitive struggle to buy and sell in that market proceeds.

First, in wind and solar markets, which procure IPPs on long term public contracts, the market is public sector determined and regulated. Second, in such public procurer markets the per megawatt (MW) unit price is fixed, after a complex bidding system, through a legally binding contractual agreement between the public energy procurer and the private sector renewable energy provider. Third, the MW contractual procurement price holds for a set period of time – at the moment it is 20 years. Once the contract is signed there is hence limited competitive terrain that the producer is involved in for that period of time, although there are still incentives to maximise operational efficiencies so as to maximize revenues.

However, this does not mean that the discipline of a competitive market does not operate. But it does so between RE providers at the outset of the auction submission process which precedes setting up the actual energy entity (i.e. through submitting bids in the REI4P model, or in municipalities, particularly metros, adapting the REI4P process to enable them to procure generation), rather than between entities in the actual delivery of renewable energy (i.e. once the entity is contractually procured, operationally set up, and connected to the grid). In other words, the competitive edge, which can be very fierce, lies in competing for access to the procurement market, rather than operating in the actual market. Competitive demands are also critical in the construction and installation process, once the contract has been awarded, in respect of procuring services and manufactured items necessary to meet the conditionalities set out in the winning proposal.

All these conditions create highly specific dynamics driving these energy GVCs. There are two critical moments that determine the value chain dynamics and drive lead firm governance activities within the chain. The first phase involves the process of winning an auction bid/proposal. Once successful, the second phase encompasses an operational process of setting up the renewable energy plant to meet the price point and other conditionalities set out in the procurement contract. Once the renewable energy plant is established it enters a third phase where maintenance activities predominate to ensure plant operations meet contractual power generation obligations.

The critical competitiveness issue in the two initial phases lies in the lead firms being able to ensure **systemic integration** between the various value chain linkages. In both these initial phases the renewable energy GVC will either succeed or flounder depending on whether its systemic foundations are correctly put in place. Hence the crucial role that the lead firms play is that of being the **system integrators** that maintain value chain integrity between the various components, players, and linkages in these two discretely foundational phases.

Phase 1 is led by private sector developers (energy utilities, or existing Independent Power Producers (IPPs), or large finance groups) acting as proposal sponsors responding to a government RfP to feed specified supply into the regulated grid energy market. Given the scale of what is required, these are necessarily large global firms/utilities working in tandem with well-established international OEMs dominating the industry. They establish a consortium, drawing on partners and service providers (both domestic and international). These range across financing mechanisms, legal services, feasibility analysis, environmental assessment, economic development, grid planning, wind mapping, and community engagement. The consortium will also include preferred international OEMs experienced in setting up the wind or solar generation system and providing its specific technology and component supplier costings, as well Engineering, Procurement and Construction (EPC) contractors to set up the renewable energy plant. There may also be a degree of fluidity between developer, OEM, and EPC in respect of roles and responsibilities.

Setting up and running such a consortium is a complex and expensive process requiring a high level of existing capability and organisational expertise, managerial capacity, resources, and access to significant financial capital. The proposals are complex, marshalling huge resources, subject to major financial risk, and require systemic integration between the various consortium service providers. The complexity comes from several sources. First, the bid usually has to meet additional social, development and economic and regulatory requirements (for example supplier local content, or training skill demands and community involvement). Second, there isn’t a specified price platform that has to be reached for the bid or proposal to be deemed successful – it is essentially a race without the tendering firms/consortiums knowing beforehand what the winning qualifying price is going to be.

The bidding/proposal phase therefore requires great systemic skill in organising a competitive consortium comprising all the required disciplines (financial, legal, engineering, environmental, etc) and the participating partners. This is the governance role of the lead developer/OEM. Without it acting as the consortium system integrator, there is no hope of successfully competing for the limited number of places available in the request for proposal phase (whether it be a REI4P auction or other government PPA process).

Phase 2 begins once a consortium has been successful, and a power purchase agreement has been signed. The proposal consortium agreements are legally solidified in order begin the actual process of producing wind or solar energy for the client. Site related works are commissioned, a wide range of service providers are utilised, and almost all of the manufactured input is sourced, and the bulk of pre-operational expenditure, including localised spending, occurs. Because they embody and distribute the financial risk and responsibility within the value chain these contracts strictly drive the process, which is why the lead developer and OEM must ensure system integration and viability of the entire process. Unless the discipline of the proposal requirements is adhered to, they are placed under huge financial risk.

Whilst the lead developer/proposal sponsor retains some form of critical control over system integration it does so in conjunction with the OEM (or sometimes the EPC contractor) in order to align the project with the required technology offerings. The system integration governance role is hence subject to deliberative dynamics amongst these core players to ensure matching of supply and regulatory obligations (such as localisation), local site contextual factors (topography, weather patterns) and OEM technology offerings. Critically, it is not simply project managing the procurement of services and goods, a supply chain function. It is a lead firm governance role, exercising power over the entire value chain to ensure the pursuit of clearly defined protocols and parameters in order to maintain system integrity of the entire process. If government policy ignores the systemically integrated nature of the GVC and the crucial role of the lead firms and attempts to enforce ad hoc localisation based on its own list of selected locally manufactured parts this is likely to fail.

In both the global wind and solar value chains setting up an IPP there is a critical role for the large global OEMs handling assembly of the generation process, and managing the supply chain of components and services, which differs between setting up wind and solar plants. This role also specifies any structural design matters for the EPC which is responsible for the civil engineering tasks and so-called balance of plant (BOP) related work. This can include a wide range of elements including equipment for grid connections such as transformers, road infrastructure, ancillary buildings, internal roads, drains, utility connections, and foundations.

The final third phase involves operations, monitoring, and maintenance of the facility. Ongoing operations and maintenance (O&M) encompass mostly services commissioned from local providers, as well as interactions with the range of project stakeholders (including grid operators, local communities, landowners, regulators). There is also the continued digital monitoring of operations and the collection of operational data throughout the operational life of the renewable energy plant. The ability of the OEM to muster a huge data base from various global operations plays a significant competitive part in its global core competence.

Structure of Local Wind Energy Value Chain

This influence of the REI4P has led for several important characteristics. Firstly, it has become dominated by global firms. The key linkages are international project developers, transnational OEMS (e.g. General Electric, Nordex Acciona, Vestas, Siemens-Gamesa, Goldwind) which are mostly US or European and handle the procurement of components and assembly of the full turbine and nacelle as the final stage before installation within the tower, international first tier suppliers (towers, blades, nacelles), engineering/procurement /construction (EPC) firms, local structural engineers handling balance of plant work, and local suppliers of various goods and services.

The OEM often applies 'follower sourcing' principles encouraging or requiring their preferred international first tier suppliers (e.g. tower, blade and nacelle turbine manufacturers) to locate plants close to the RE plant rather than importing such critical components. Ongoing operations and maintenance (O&M) involve mostly services commissioned from local providers (crane operators, wind tower maintenance technicians) or through the OEM structures (locally or internationally), as well as IPP interactions with the range of project stakeholders (including grid operators, local communities, landowners, regulators).

The follower sourcing model usually applied internationally starts with localising production of *towers*, then *blades* (the most expensive component to localise other than production of key elements of the turbine itself), and then *nacelles,* including assembly of imported components. Follower sourcing ensures that critical technical standards are maintained, logistic import costs are cut, and delivery reliability is maintained. But OEMs only encourage follower sourcing if a combination of systemically integrated factors is in place – sufficient market demand, and continuity and predictability of window bids over time to ensure sustained market demand is guaranteed by the country's RE programme. Moreover, if the host country has an industrial policy specifying clear and key local content requirements that need to be met, coupled with appropriate incentives, then follower sourcing will be tailored to each country context.

The local content requirement program to build domestic technological capabilities and skills was also distorted by an over emphasis on BEE ownership criteria to satisfy short term vested political interests and government transformation policies. Lead firms in the wind energy value chain took this as an indication that government was less interested in building an industrial base and more concerned with community impact issues.

Unfortunately, from 2016 onwards, once the renewable energy IPP model had become firmly established as successful private sector driven process, and was fairly immune to corruption and state capture by predatory elites, the government attempted to disrupt the process. The Zuma government didn't reverse the REI4P policy but instead derailed its smooth functioning by disrupting critical aspects of the program - not initiating the further bid windows, stalling implementation, encouraging Eskom to engage in 'malicious compliance', and a variety of other indirect institutional processes to stall the entire renewable energy platform. In short government succeeded in blocking the critical continuity and predictability flow of REI4P. This uncertainty injected into the program had a very negative impact on follower sourcing, and this cascaded all the down the value chain. Instead of vertical alignment being facilitated, government ensured the opposite with disastrous implications for localisation of goods and services, and linkage development in terms of skills and innovation.

The first tier MNC tower supplier operating in Atlantis was eventually forced to stop production. Negotiations with international blade and nacelle MNCs broke down. Instead of these global manufacturers following through plans to establish local plants these large first tier suppliers withdrew from setting up subsidiaries in South Africa. Local second and third tier suppliers of goods and services suddenly found their market drying up and went out of business.

General Observations

In summary for most emerging market economies, localisation of the supply chain is dependent on the systemic integration of the wind energy GVC. If this is disrupted, then it fractures the value chain dynamics with a negative rippling effect all the way down the chain.

The breakdown of continuity and predictability in the auction bidding process had a disastrous effect on the wind energy value chain and localisation. It disrupted plans of investors across different tiers, forced major adjustment costs on suppliers, resulted in company closures and blocked new supplier initiatives, caused a shedding of carefully developed skills capabilities, resulted in major job losses, and paused important local content policy reform efforts.

Hence, government policy aimed at creating a strategic green industrialisation path through localisation of suppliers requires policy makers to engage in a radical shift in how they conceptualise the local content problem, understand the constraints, and formulate implementable policy solutions. This requires embracing a GVC policy perspective encapsulating the systemic totality of the value chain and the key role of the lead firms as maintain its systemic integrity rather than simply the ad hoc intention of localising this or that component or set of suppliers.

The Photovoltaic Value Chain

Overview

The value chain of PV from raw material to generation is set out in Figure 2 (Green Rhino Energy, 2016).

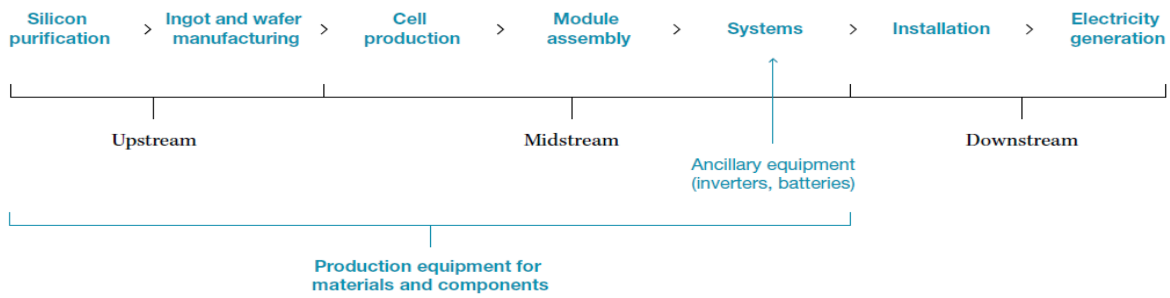


Figure 2: Crystalline PV supply chain production stages

The *upstream* linkages consist of silicon purification to cell production. The *midstream* component segments of module assembly involve cells being soldered together onto glass and aluminium sheets, with the electrical junction being done by hand or automatically and encapsulated in glass sheets to form an assembled panel which is cooked in a laminating machine. In addition, there is also the production of ancillary equipment (inverters, batteries, cables etc). The *downstream* linkages create the generation system - i.e., the installation of the total system and the subsequent generation of electricity. This involves a process of combining the assembled modular panels with complementary equipment (batteries and inverters) to deliver electricity to the grid or individual commercial establishments or residences.

The global solar PV value chain used to be primarily driven by US, German, and Japanese lead firms up until the turn of the millennium (Carvalho, Dechezleprêtre and Glachant, 2017). However, it is now heavily dominated by mainland Chinese firms. This is especially the case in respect of the production of solar PV cells – wafer crystalline and thin film cells. Crystalline PV cells now account for over 90% of land-based PV systems.

The upstream linkages (silicon purification to cell production) are very capital and resource intensive and the ability to cut costs and mobilize the necessary capital and technology resources has resulted in a major domination of these segments by firms located in China.

The midstream component is labour intensive activity, requiring specialist technology and expertise, and space is created for the entry of other players. Module production creates the most PV manufacturing jobs in the value chain – estimated to be 46%. This midstream activity is also dominated by specialist large global transnational firms, many of them Chinese, but who are not necessarily averse to locating subsidiaries in other countries or entering into joint ventures with local firms.

The downstream linkages tend to be most profitable, more amenable to subsidies, protective tariffs, and local content regulations requiring a certain percentage of technologies used for local PV markets to be locally sourced. However, localisation and the building of domestic capabilities does require achieving a certain level of scale in demand. Otherwise, imports will dominate this segment. Hence downstream linkages have tended to remain within industrialised countries or emerging economies that have focused on localisation. This has forced Chinese MNCs to set up manufacturing plants in those countries that have aggressively pursued localisation.

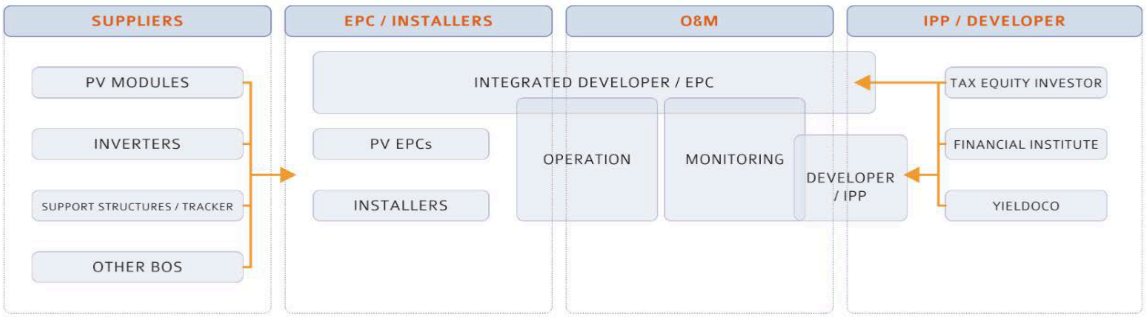
Photovoltaic Value Chain in South Africa

The PV GVC controlling panel assembly in South Africa is dominated by a small number of Chinese transnational manufacturers who export assembled modules. This is partly a function of bank guaranteed financing but should change in the future if the local assembly industry matures and achieves the requisite level of scale.

There are examples of local assembly plants in South Africa – ARTsolar and Seraphim – who do module assembly of panels. ARTsolar has grown on the basis of a collaboration agreement with Talesun Solar, a leading global Chinese photovoltaic (PV) module manufacturer. Seraphim is a Chinese Tier 1 supplier which has opened up a local subsidiary. Other panel assembly MNCs have tried to set up subsidiaries in South Africa but as a result of the policy inconsistency encountered as REI4P broke down and local procurement foundered, have withdrawn from the domestic market.

Inverters are primarily imported but local production does exist and could be expanded (Semelane, Nwulu, Kambule and Tazvinga, 2021). Italian based firm Enertronica Santerno has established a subsidiary for manufacturing inverters with over 40% local content. In terms of local battery production selling into the residential market there is a local plant which is refurbishing lithium batteries (Revov), as well as a number of firms assembling batteries using lithium cells imported from China (Blue Nova, Freedom Won, BSL, SolarMD, and Hubble). The solar PV value chain can be conceptualised as shown in **Figure 3**.

Figure 3. Providing demand-side services in developing solar PV markets



The solar PV market in South African can be divided into three major segments:

- Large scale utilities (IPPs) establishing solar farms through REI4P to feed into the Eskom transmission grid.
- Medium to large scale commercial and industrial users installing large banks of solar rooftop panels (SSEG) with inverters and large battery storage to run their commercial or manufacturing operations and selling the surplus back into the municipal grid.
- Small scale residential consumers installing a relatively small number of solar panels with an inverter and a couple of lithium batteries providing electricity primarily for own home usage.

Apart from generating electricity all three segments are important consumers of downstream products and services, and hence hold the potential for increased localisation of manufacturing and service sectors. The growth of these three sectors, especially those dependent on SSEG, have been accelerated by the catastrophic decline in Eskom being able to provide energy security and electricity supply resulting in the current electricity crisis. This has increasingly resulted in commercial, industrial, and residential electricity consumers seeking to move off a total reliance of the Eskom grid and finding various levels of energy independence. The dynamics of this process within these segments in captured below:

Utility value chain: This is comprised of the following distinct linkages - project developers, EPC companies, operating and maintenance companies, project owners and the utility or power purchaser (see **Table 1**).

Table 1. Role players in the utility PV value chain (South Africa)

Project Developer	Project developer are international companies and their value added comes primarily from their expertise in the financial and legal issues of the project. They are typically responsible for project development activities including site identification and evaluation, system performance, environmental and grid connection studies, permit and license acquisition, bid applications, community negotiations, and appointment of EPC and O&M contractors. Project ownership of

	the IPP is generally a special purpose vehicle/consortium comprising of the numerous parties, the developer, equity partners, community trust, BBBEE partners, and potentially the local utility.
Engineering, Procurement and Construction Contractor (EPC)	EPC are international MNCs (e.g. Siemens) and combine technical knowledge and expertise. They oversee the design and construction of the utility-scale project. Local EPC contractors have limited expertise and knowledge of the PV technology and PV project logistics. Two EPC contract models exist in South Africa: **Construction Management (EPCM):** The project developer is responsible for design, construction, and appointment of sub-contractors; appoints an EPCM contractor who manages on-site contractors appointed by the project developer. The risks are shared between the developer and equipment suppliers. There is greater flexibility of the project scope and an opportunity to negotiate the warrantees with the suppliers. **EPC Wrap and Engineering Procurement:** The EPC contractor is responsible for the design, execution, and performance of the entire PV project, directly negotiates with equipment suppliers and appoints sub-contractors. All warrantees on equipment and processes are issued in the name of the EPC contractor, who is solely responsible for the performance of the system and bears all the risks.
O&M	O&M responsibility for the first few years generally lies with the EPC contractor. Skills transfer between the project owner's team and the EPC contractor ensures smooth transition after the O&M agreement expires and then handed over to the project owner who may or may not sub-contract ongoing monitoring and maintenance requirements.

In terms of input components, PV panels, inverters, and mounting hardware/trackers are among the biggest expenditure items - about 67% of the total project cost.

Large commercial and industrial value chain: Key linkages are EPC and technology system integrator installers, O&M, project owners and users (see **Table 2**).

Table 2. Role players in the commercial and industrial PV value chain (South Africa)

EPC and System Designers	EPC Wrap procurement is the norm. EPC contractors are responsible for site identification and evaluation, client needs analysis, energy modelling, design, installation, commissioning, municipal grid linkage.
Inverter manufacturing	Imported or local producers OR refurbished
PV module assembly	Imported or local possibility
Lithium batteries	Imported or refurbished
O&M	Daily monitoring of plant performance and an annual servicing. EPC contractors or installers of the system provide training in basic operations, emergency procedures, safety instructions, and cleaning of solar arrays.

In terms of input components PV panels, inverters and mounting hardware are the largest cost items - about 75% of the total project costs.

Residential and small commercial value chain: Most companies are small and medium sized and serve as system designers, PV system component procurers, installers, and maintenance providers. Monitoring of system performances is done off-site remotely over the internet (see **Table 3**).

Table 3. Role players in the residential PV value chain (South Africa)

System Designers and Installers	System designers are usually integrated with an installer firm or operate with one as associates. They are responsible for on-site installation of the PV system and explaining how it works to the owner. An installer's team generally consists of a project manager, a certified electrician and a few workers.
Inverter manufacturing	Imported or local producers OR refurbished
PV module assembly	Imported or local possibility
Lithium batteries	Imported or refurbished
O&M	Occasional maintenance and servicing of the system is done usually by the same company that installed the system.

In terms of input components, PV panels, inverters, batteries and installation are the main cost items for household PV systems.

General Observations

The current electricity supply and price crisis has created an entirely new dynamic driving the renewable energy value chain in South Africa. As stated by Isabel Fick, GM for system operations at Eskom, as of mid 2023 there is already 6,200MW of variable renewable power connected to the grid[2]. This compares with about 40,000MW of installed coal-fired power.

Solar PV has almost doubled between mid 2022 and 2023 to about 4,800MW of installed capacity. According to Fick, "Rooftop solar has overtaken generation from large solar PV plants and is now the biggest variable and uncertainty we have to deal with on a daily basis on our network". The unintended consequence on the solar value chain of the increasing proliferation of commercial and residential SSEG has been profound. The swelling wave of commercial and industrial businesses, as well as middle class residences, embracing SSEG through installing solar renewable energy has caught national and local government off guard. Government cannot halt the process but is desperately running behind in an attempt to catch up and formulate adequate policies to enable some form of regulation. Municipal government has shifted in a very short period from regarding itself simply as a distribution agency for Eskom generated and transmitted electricity and collecting a share of the revenue to finding a new place for itself as a local co-generator of electricity through procuring this directly from private sector owned solar based plants. Even Eskom, the last bastion of coal fired power stations, is trying to set up its own solar farms to produce renewable energy on decommissioned power station land.

[2] Erasmus - Business Live, 14/09/2023

This shift in the energy landscape to install SSEG (and IPP) generated solar power is creating a rapid increase in the scale of demand for solar inputs. Coupled with a resurgence of the REI4P program this is having a major impact on the market supply of goods and services. Demand for solar panels, inverters, batteries, and the concomitant services to install them is exceeding the supply of such goods and services beyond current import and local manufacturing capacity. The rise in the scale of demand creates the potential tipping point opportunity for creating the necessary scale for localised production of various links in the value chain - assembled panels, inverters and batteries – as well as an expansion of the service skill base linked to installation and maintenance. This new expansion of the solar market is not only creating the conditions for local insertion into the solar value chain. It is also ensuring some forms of localisation of its own accord.

However, maximising the localisation possibilities requires policy intervention on the part of government at the national and local levels. The different solar market segments are interrelated, and this relationship impacts in terms of scale and localisation potential. A sustained national REI4P program to ensure continuity and predictability of utility scale solar IPP operations is the bedrock to stimulate and stabilise some forms of localisation, primarily through partnerships with the lead firms and encouraging establishment of local subsidiaries. As metros and municipalities contract IPPs to meet some of their renewable energy requirements, then it is critically important that they follow REI4P and include some local content requirements in the RfPs. Unfortunately, given the supply crisis and the urgency of producing sufficient energy, the dominant tendency is for the metros to underemphasise local content requirements in their RfPs. This is a short-sighted view which will impact negatively on localisation and the ability to drive down costs of locally goods and services through increased economies of scale. It is not in the long terms interests of the metros to be totally dependent on imported components and to undermine REI4P.

A key requirement for creating significant scale lies in significantly ratcheting up the high PV solar adoption rate in the commercial/industrial and residential market segments[3]. Moreover if metros adopt open wheeling agreements with large/medium sized commercial and smaller residential consumers which introduce feed-in tariffs on a reasonable basis, allowing all energy surpluses to be sold back into grid at price which provides sufficient incentive, and set up low cost metering units to manage the process, this will further stimulate the residential and large commercial/industrial side of the SSEG market, accelerating the economies of scale required to boost localisation.[4]

Key Policy Recommendations for Aligning Value Chains and Innovation Systems

This section is divided into two parts; in the first part, we present important policy recommendations relating to GVC management and stimulation in South Africa, with specific reference to localisation (Morris, Robbins, Hansen and Nygard, 2021). In the second section, we focus only on the recommendations for the management of innovation vis-a-vis innovation systems. We note that the two sets of recommendations cannot be viewed in

[3] This approach is in line with the SAREM 2021.

[4] In terms of expanding residential SSEG two key issues stand out – a) the feed-in price has to produce sufficient incentive to feed surplus energy back into the municipal grid, and b) the cost of installing an appropriate meter to do so has to be low (or free) to eliminate potential constraints in deciding to do so.

isolation; any attempt to align the National Innovation System with GVC needs has to be undertaken simultaneous to a broader set of initiatives addressing issues such as corruption, rent seeking,

Recommendations for Value Chain Management

A. Public procurement is a powerful instrument for localisation, as illustrated in the case of the REI4P. Political objectives, which are focused on advancing factional interests within society, whether these are legitimate or not, cannot take priority and become the primary objective of a localisation initiative. If this occurs, then the public good being advanced by localisation will be distorted, be prone to being highjacked, and become open to corruption.

B. It is important to clarify the scope and range of localisation. Localisation does not necessarily refer to a particular range of distance. It means being supplied from the domestic economy irrespective of metropolitan or provincial boundaries, as long as what is being sourced is being produced somewhere within the national boundaries of the country.

C. If localisation is essentially about increasing value added, growing domestic revenue, and expanding jobs, then what matters is the fact of local industrial activities being set up rather than the issue of who owns the firms/enterprises that are engaged in such activities. If international firms – multinationals or large foreign suppliers - set up subsidiaries within the domestic economy and local industrial activity is expanded, then localisation will have had some measure of success. To focus on the ownership of such firms as the primary indicator of successful localisation will severely limit the full range of opportunities that arise to expand the public good elements.

D. Localisation has also to be more than simply sourcing inputs from a local agent. It must meet the criterion of adding value, revenue generation, and job creation within the domestic economy. Simply diverting imports through locally owned firms or agents is not enough. Localisation will simply increase the cost without additional advantage accruing to the domestic economy.

Recommendations for Innovation Policy

A. International firms (utilities, developers, OEMS) dominate the renewable energy landscape. These lead firms drive the global value chains (GVCs) that determine supplier requirements and sourcing patterns. The wind and solar industries globally are driven by the decisions and operations of these lead firms. Domestic suppliers have very limited power as independent operators outside of these GVCs. Government policy can intervene to create an enabling environment to facilitate localisation, but it has to work with the lead firms in doing so rather than trying to substitute for their value chain role. If policy ignores the determining role that GVCs and lead firms play in the wind and solar renewable industries, then it is doomed to treat localisation as a complex, albeit insoluble, policy puzzle.

B. Localisation is also not only about stimulating domestically manufactured goods. It is also about services. Unfortunately, REI4P has tended to focus its local content provisions requirements on manufactured items. However, a critical lesson from the wind energy value chain is that locally provided intangible services to the IPPS have also been stimulated by the auction-based system adopted in South Africa. The lesson that emerges from this is that a comparative advantage that locally based service firms have demonstrated falls between the cracks in the way that localisation has been understood and incorporated into the renewable energy policy framework. Innovation policy, in particular, needs to include business service innovation as a means to building competitive advantage.

C. The critical issue from an energy policy, innovation policy and implementation perspective is ensuring that government initiatives at national or local level maintain long-term continuity and repetitive predictability of any renewable energy program if localisation has any chance of sustainability (Potts and Walwyn, 2020).
D. Innovation policy to support engagement in GVCs should not be dependent on single instruments but must adopt a mixture of supply and demand side policies, including policies for encouraging research and development, technology transfer, training, investment in capital equipment and public procurement (Walwyn, 2021; Walwyn and Naidoo, 2020)

Priorities for Research, Development and Innovation

The two studies of the wind and solar GVCs, and other studies of a similar nature (GreenCape, 2021; Walwyn, Magadimisa and Niekerk, 2021; Potts and Walwyn, 2020; El Baz, Laguir and Stekelorum, 2019; Luke and Heyns, 2019), raise important priorities for RDI programmes within the National System of Innovation. Such priorities are now presented.

A. *Centres of Excellence*: there are few RDI centres within South Africa's public research organisations which are focussed on logistics and GVCs. As a result, the important functions of knowledge generation and human resource development, the latter particularly at post-graduate level, are not well served. Additional investment in areas such as economic studies of global value chains, the status of South Africa's logistics systems, trends in partnering and communications, domain-specific expertise to support localisation and sustainability should be an immediate priority.
B. *Green Certification*: GVCs are slowly moving towards greater emphasis on supply chain sustainability and the circular economy, with penalties for imported goods which are associated with high carbon emissions. Green certification is intrinsic to this process and is now an important area of development for countries wishing to build or maintain a strong role within GVCs. Given the novelty of this trend, it is critical that innovation systems include such RDI within their portfolios.
C. *Digital Platforms*: digital platforms such as Uber and Linebooker have changed the relationships between logistics companies and service providers. The ongoing implications of these new platforms for logistics and GVCs are profound. It is critical that South Africa has local expertise in the development and maintenance of such platforms, and how they can support greater integration of the country within GVCs.
D. *Sustainability*: there is a growing relationship between participation in GVCs and attention within companies to the sustainable development goals (SDGs), which is creating new demands on the innovation system and public universities (Walwyn, 2022). Public research universities should strive to respond to this change by making SDGs central to all teaching, and introducing intradisciplinary studies as important parts of all degree and research programmes (Walwyn, 2022).

E. *Logistics and Connectivity*: finally, in this section, we emphasise the importance of ongoing RDI within the general area of logistics/supply chain management, with the goals being human resource development and the generation of new knowledge/application of existing knowledge in order to upgrade South Africa's technological capability in GVCs. Several areas for suitable investment are covered in current references (El Baz et al., 2019; Luke and Heyns, 2019).

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