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Technology Development in South Africa: The Case of Wind and Solar PV

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Technology development in South Africa: The case of wind and solar PV [1]

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Abstract

This paper examines the political economy of technology development in the context of South Africa's emerging utility-scale, privately generated renewable energy sector. Focussing on the wind and solar PV industries, the paper explores how international dynamics in manufacturing, investment and trade that involve increasingly global industries, are interacting with territorial factors embedded within South Africa's unique economic, social and political context. While South Africa's renewable energy industry has been celebrated internationally, there are tensions between commercial priorities, and requirements for economic development including local content. The paper merges perspectives from global production networks and the literature on technological innovation in low and middle income countries in order to analyse the potential for the development of innovative capabilities in South Africa's renewable energy sector. The paper provides rich empirical content including challenges to the definition and implementation of local content requirements, as well as the involvement of key national and international actors.

Keywords

Innovation, local content, renewable energy technologies, global production networks, South Africa

1. Introduction

South Africa's utility-scale, commercially generated renewable energy sector constitutes a small but significant source of generation within the country's historically coal-dependent and now crisis-ridden national electricity sector[3]. This paper discusses how renewable energy technologies being deployed, assembled and/or manufactured in South Africa are embedded within increasingly globalised networks of project developers; engineering, procurement and construction companies; technology manufacturers; and flows of national and international investment. Furthermore, the requirements of finance and investment to deploy 'internationally proven' expertise and technology has a significant determination over the renewable energy technological trajectories being developed in South Africa. Meanwhile, key tensions exist within national government between the demands for least cost technology, and national priorities for the establishment of a local manufacturing industry and job creation.

South Africa's grid connected renewable energy sector is being developed under the country's renewable energy independent power producers' procurement programme (RE IPPPP) launched in 2011. RE IPPPP is a competitive bidding system that permits the construction and integration of renewable energy generation by independent power producers (IPPs) to the country's monopoly controlled transmission grid. Under RE IPPPP, projects are required to adhere to potentially progressive criteria for economic development, including local content as a key focus of this paper. These criteria relate to government commitments to the green economy and a labour intensive industrialisation path that are at odds with the country's declining manufacturing sector and an unemployment rate of 40 per cent[4]. As a result of the increase in thresholds and targets for local content since the start of RE IPPPP, a number of manufacturing and assembly plants have been

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[3]As the country faces its worst electricity crisis for 40 years, South Africa's utility Eskom has been carrying out regular load shedding since mid-2014.

[4] This figure includes formal definitions of 25 per cent unemployment in addition to 'discouraged work seekers' who have given up finding work.

set up or are under development for low technology components including towers for wind and solar photovoltaic (PV) modules and inverters. In addition to assisting project developers to meet local content requirements under RE IPPPP, a number of these facilities anticipate the potential export of their products both to the African continent and elsewhere. However as the paper explores, loopholes in the regulations have resulted a number of solar PV developers side-stepping local content requirements and importing stock from abroad. Furthermore, others have argued that the limited market size created by RE IPPPP to date is inadequate to generate local production and therefore the technological upgrade and job creation impacts will remain at the lower and medium technology levels (Rennkamp and Westin 2013). This echoes Bell and Albu's assertion (1999) that local content requirements alone are more likely to benefit short-term activities than a long-term local manufacturing industry with high levels of domestic ownership and 'technologies capabilities'.

While RE IPPPP represents an unprecedented success in terms of its transparent regulatory framework, the investment it has brought to the country, and the rapid construction of renewable energy that has resulted, concerns have been raised over the effectiveness of these economic development criteria. With this in mind, this paper considers the significant challenges that exist to the creation of long term manufacturing capabilities and a national supply chain in renewable energy technologies. The paper's objectives are threefold. Firstly to provide a rich empirical description of the challenges inherent within the definition and implementation of RE IPPPP's local content requirements. Secondly to analyse key actors involved in South Africa's renewable energy technology supply and manufacturing and in doing so, how international trends are merging with the country's unique economic, political and social context. Finally to consider the implications that such a context may have for technological diffusion, innovation and skills in the country. The research focuses on the wind and solar PV industries which form the majority of projects allocated under South Africa's RE IPPPP and for which information is more publicly accessible as compared to concentrated solar power (CSP)[5].

The paper's analytical approach is informed by the literatures on technological capabilities (Bell 2009) and global production networks (Coe 2012, Curran 2015). Both literatures facilitate an analysis of the complex and multi-scalar relationships that exist between networks and institutions and the embedded nature of technology within a national and international political economy. This political economy involves interactions between endogenous factors such as the introduction of a regulatory framework for renewable energy independent power producers, and international dynamics such as investment trends and trade disputes.

The structure of the paper is as follows. Section 2 discusses the methodology used to undertake the research. Section 3 discusses the key bodies of literature that have informed the analytical approach of the research, namely technological capabilities and global production networks. Section 4 situates South Africa's utility-scale, renewable energy industry within its national context, outlining the current and potential investment in manufacturing that has emerged, the international trends that have reacted with and influenced these national level developments. Section 5 explores national commitments to the green economy and some of the challenges to achieving a renewable energy manufacturing industry in South Africa. Section 6 examines some of the challenges and the loop holes that have resulted from the manipulation of local content requirements to the detriment

[5] See WWF (2015) for a more detailed investigation of the potential for CSP industrialisation in South Africa

of a potential industry. Sections 7 and 8 examine the specifics of the country's wind and solar PV industries respectively and how international corporate dynamics have reacted with South Africa's unique national context. The final section concludes.

2. Methodology

This paper forms part of a longer term political economy analysis of South Africa's electricity sector. In particular it draws on extensive and in depth field work undertaken over a period of six months between October 2013 and January 2015, including approximately 40 interviews with members of the renewable energy industry, government departments, the electricity utility, finance, civil society and labour. The field work also involved six site visits to renewable energy projects and manufacturing/assembly facilities. A number of the interviews are cited here but individuals have been heavily anonymised due to the commercially and politically sensitive nature of the material. For the same reason it has not been possible to disclose detailed information pertaining to the facilities visited. The paper also draws from significant content analysis of government documents and policies as well as grey literature on renewable energy technology. One challenge to this is that many of the bid documents for RE IPPPP in which the economic development requirements are specified are not available in the public domain. Consequently, I have drawn from publicly available secondary sources. The research is also informed by a long-term and systematic consultation of media sources on the renewable energy industry in South Africa and globally, including: *Engineering News, ESI-Africa, Wind Power Weekly* and *Recharge News.* Given the breath of the subject matter, the research does not pretend to be exhaustive and in light of the fast moving nature of the topic inevitably contains some empirical gaps.

3. Analytical framework

The analytical framework draws from the literatures on technological capabilities and global production networks in order to analyse the complex relationships between networks and institutions, and the embedded nature of technology within a national and international political economy. The paper also fits within a growing body of research on technological innovation and the creation of renewable energy manufacturing industries in the emerging markets of China and India (Altenburg et al 2014, Lema et al 2013, Fu and Zhang 2011), green industrial policy in developed countries (Pegels and Lütkenhorst 2014), and comparisons between the two, for example China and Germany (Dunford et al 2013). However limited consideration has thus far been dedicated to South Africa with exceptions being Rennkamp and Boyd (2013) and Rennkamp (2013). This paucity of analysis is largely due to the very recent emergence of a renewable energy industry in the country and related manufacturing plants. This paper therefore contributes to an emerging knowledge base in this area.

Following Bell and Albu (1999:1717), technology, rather than just machinery "is a much more complex body of knowledge, with much of it embodied in a wide range of different artefacts, people, procedures and organisational arrangements". Technological change therefore goes beyond the mere diffusion of hardware such as designs, complete equipment and installation services, which was a common perspective on production and trade until late 1960s (Bell 2009). Rather, 'software', such as skills, system building and knowledge flows is significant for its ability to contribute to the accumulation of knowledge stocks and resources often referred to as 'technological capabilities'. Technology and technological innovation therefore, are part of numerous inter-linked, comprehensive and interactive processes and bundles, for which reason the transfer of physical assets alone will be inadequate to ensure the development and acquisition of the knowhow necessary to reproduce technology hardware (Lema et al 2015). This is particularly the case in the international solar PV and wind industries which are growing in technical complexity. The implications this has for South Africa to generate its own manufacturing base and technological capabilities are significant.

Related concepts which apply here include: the nature of technology transfer to developing countries, including definitions of research and development (R&D); knowledge spill-overs and knowledge leakage (Bell and Pavitt 1993); industry clusters and innovation systems (Bell and Albu 1999); and the Asian driver debate at the centre of which is the notion of China as the 'workshop of the world' (Lema et al 2013:40). Long-standing debates over the relationship between imported technology and indigenous technological development in low and middle income countries (Lall 1993) are similarly relevant. Such debates relate to Mokyr's (1998) discussion on the difficulties of transplanting foreign technology into a country where adapted institutions have not evolved jointly, as a result of which serious incongruities and disruptions could result. Discussions by Byrne et al (2011:29) on the increasing 'knowledge embeddedness' of technologies and the requirement for increasingly specialised knowledge for the creation of technical change are also central to the challenges South Africa faces in establishing technological capabilities in renewable energy. Finally such themes link to on-going yet unanswered questions over what the role of technology transfer should be in contributing to solutions to climate change mitigation and climate finance (Lema et al 2015, Ockwell and Mallett 2013).

The concept of embeddedness is a key conceptual category in the literature on Global Production Networks (GPNs) which is concerned with the interconnectedness and uneven development of the global economy and on power relations within global relationships (Coe and Yeung 2015, Chester and Newman 2014). The GPN methodology is engaged here in order to examine how relationships between national dynamics and international forces have influenced technological pathways and renewable energy supply chains in South Africa to date. Furthermore the GPN approach analyses interactions between local actors and production networks at various geographical sites and scales (Bair 2008, Coe 2011); focuses on institutions other than the firm such as government agencies, trade unions, civil society and multi-lateral agencies; is concerned with multi-scalar networks between the local and the global; assumes governance arrangements as complex; and examines impacts on both firms and the territories within which they are embedded (Coe 2012:390). GPNs are therefore much broader than the related perspectives of Global Value Chains (Gereffi et al 2001) and Global Commodity Chains (Bair 2005) which tend to make linear assumptions about the nature of production systems (Henderson et al 2002).

It is only recently that the GPN literature has started to engage with questions of trade and production in renewable energy. Current contributions, to which this paper adds, include Dunford et al (2013) on Chinese and German solar energy industries, Gallagher and Zang (2013) on China's PV industry, and Curran (2015) on trade policy and the solar PV industry. This paper also aims to tackle a number of gaps that have been identified within the GPN literature, namely, analysis of the role of finance (Coe 2014) and considerations of competitive dynamics (Coe and Yeung 2015). It also responds to the call from Dunford et al (2013:16) in their analytical comparison of the solar PV industries of China and Germany, for greater consideration of the political economy of trade and development and geographical interdependence.

The following section now undertakes an analysis of the national and international dynamics in which an emerging renewable energy technology industry in South Africa is embedded.

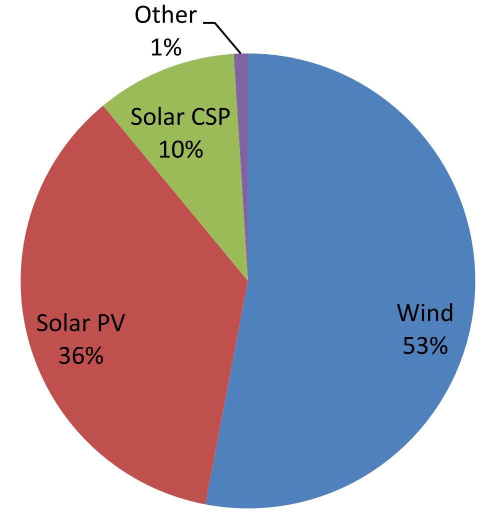
4. National context and international dynamics

i) Renewable energy in a national context

South Africa's political economy is characterised by its minerals-energy complex (Fine and Rustomjee 1996), a system of accumulation whose historical core has been shaped by cheap coal combined with cheap labour for the generation of cheap electricity for export-oriented mining and minerals beneficiation. The monopoly electricity utility Eskom, now cash strapped and crisis ridden, sits at the heart of such a system. The country depends on coal for 90 per cent of its electricity supply and is the world's 14^{th} biggest emitter of greenhouse gases. However the past decade has seen notable shifts in policy, discourse and practise. Despite South Africa's historical and continued dependence on abundant low-cost coal, the country has become a leading destination for renewable energy investment. Since mid-2015 solar PV has become competitive with new build coal-fired power plants (ESI-Africa 2014) in keeping with growing global trends which see renewable energy reaching grid parity with conventional sources of energy generation (UNEP/BNEF 2015).

Various stalled attempts in recent decades to introduce both independently procured power and renewable energy into the country's monopoly controlled, coal fired grid (Eberhard 2005) eventually culminated in a number of recent significant national developments for the introduction of renewable energy (Baker et al 2014). Notably in May 2011 the Department of Energy (DoE) launched the country's first integrated resource plan for electricity (IRP). While this allows for an increase in coal-fired generation it also allows for 17.8 gigawatts (GW) of capacity to come from renewable energy which will produce approximately nine per cent of electricity supply by 2030. The IRP was swiftly followed by the launch of South Africa's renewable energy independent power producers' procurement programme (RE IPPPP) in August 2011, a competitive bidding process for utility-scale renewable electricity which has now undergone four bidding rounds (Eberhard et al 2014). Under RE IPPPP renewable energy generation will be built, owned and operated by independent power producers (IPPs) which are project financed (Baker 2015). IPPs sell their power to Eskom under a twenty year government backed power purchase agreement.

Figure 1: Allocation by technology, Rounds 1 to 4 of RE IPPPP



At the time of writing, 92 projects amounting to 6.3 GW had been approved under the first four bidding rounds of RE IPPPP, of which 3346 megawatts (MW) for wind, 2297 MW for solar PV and 600 MW for CSP (see Figure 1). Thirty seven projects had been connected to the grid by June 2015 for which a combined investment value of R192 billion (approximately $14 billion) has been committed. In August 2015 the Department of Energy (DoE) announced that a further 6.3 GW of capacity will be procured in upcoming rounds.

South Africa's procurement programme is unique in that the projects in question must include local communities as equity shareholders, as well as contribute to economic development criteria. Projects that bid under RE IPPPP are scored 70 per cent on price below a certain tariff cap which decreases with each round and 30 per cent on economic development criteria. These are outlined in an economic development scorecard which aligns with the country's Broad Based Black Economic Empowerment (BBBEE) legislation and contains seven requirements that project developers must comply with, as indicated in Table 1. These criteria, of which local content forms 25 per cent, are significant for a country with high levels of unskilled labour, unemployment and national priorities for the generation of labour absorbing industries. While the economic development criteria are potentially very progressive, a number of concerns have been raised over their long-term effectiveness (Baker and Wlokas 2015), including as a key focus of this paper, the extent to which they may help to generate a local manufacturing industry for renewable energy.

Table 1: Economic Development Criteria	
Economic Development Elements	**Weighting**
Job Creation	25%
Local Content	25%
Ownership	15%
Management Control (by black owned companies)	5%
Preferential Procurement	10%
Enterprise Development	5%
Socio-Economic Development	15%
Total	**100%**

Under RE IPPPP, local content is defined as "the total costs attributed to the project at the commercial operation date, excluding finance charges, land and mobilisation fees of the operations contractor" (DoE 2011:8). As local content is defined as a percentage of project expenditure spent in South Africa its accurate measurement has been problematic. One reason for this is because it is based on Rand value, which as a floating exchange rate is subject to significant fluctuations over time and in turn affects the cost of imported products (Ahlfeldt 2013:xxi). Notably there has been a significant devaluation of the Rand since 2012.

Thresholds and targets for local content have increased between each bidding round (see Table 2). While under rounds one and two it was possible to meet the local content requirements through 'balance of plant', by the third bidding round the threshold for local content, particularly for wind, was sharply increased. This means in principle that project developers have to source more of their project content locally and for some components to have been manufactured or assembled in country. The extent to which this has been achieved in is a key focus of discussion in Sections 6, 7 and 8.

Table 2: Local content targets as percentage of overall project spend						
	Round 1		Round 2		Round 3	
Technology	Threshold	Target	Threshold	Target	Threshold	Target
Wind	25%	45%	25%	60%	40%	65%
Solar PV	35%	50%	35%	60%	45%	65%
Solar CSP (without storage)	35%	50%	35%	60%	45%	65%
Solar CSP (with storage)	25%	45%	25%	60%	40%	65%

Source: Adapted from DTI (2013b)

ii) International dynamics

In parallel to the national policies that facilitated the emergence of a utility-scale renewable energy sector, a number of exogenous factors, particularly as regards the shifting geographies of renewable energy production, have played a role. These factors include impacts of the 2008 global financial crisis on renewable energy markets in Europe and US which saw the reduction or removal of subsidies by governments and led to policy uncertainty and a slump in project development. Subsequently, renewable energy development and related investment started to shift to developing countries, including South Africa. The accompanying global overcapacity in technology hardware has led to fierce competition between foreign developers and technology suppliers and is reflected in the dramatic tariff drops between rounds one and four of RE IPPPP, particularly in the case of solar PV technology.

International norms of project finance applied by debt financiers and equity investors have a significant determination over the technology that gets selected for projects approved under South Africa's RE IPPPP (Baker 2015). These norms favour contractors and technology suppliers with extensive experience. That the technology in question be 'proven' is a fundamental consideration for the lender with regards to a project's commercial viability (Yescombe 2013). This relates to Lall's (2001:287) assertion that the provision of capital by large international firms in the equity shareholding of projects often comes packaged with "technical know-how, equipment, management, marketing and other skills". Under project finance norms, national requirements for local content are considered a 'risk' by a number of private sector financiers. For this reason and as discussed in more detail below, contracts for engineering procurement and construction (EPC), operation and maintenance (O&M) and technology supply for RE IPPPP projects have to date been dominated by international companies with expertise in project development for utility-scale projects (Ahfeldt 2013).

5. Green Economy

National commitments to the green economy are included in a number national plans and documents on growth and industrial policy. Firstly, the Green Economy Accord, published by the Department for Economic Development and one of the six priorities of the New Growth Path was signed in November 2011 by representatives of government, business, organised labour and a small number of 'community constituents'. The Accord has a target of 300 000 new jobs through green investments by 2020 of which 50 000 in the renewable energy sector (EDD 2011:19), though it is unknown how these figures were calculated (Musango et al 2014:11). Secondly the 2013-2016 Industrial Policy Action Plan proposes to revise RE IPPPP's local content requirements in order to achieve an "increased local content threshold for renewable energy projects in line with the development of a competitive local renewable energy manufacturing industry" (DTI 2013a:122). Thirdly, the National Development Plan highlights the need to develop the renewable energy sector (National Planning Commission 2013). A number of educational initiatives have also been set up for the creation of 'green technical skills', including at various technical colleges across the country as well as the establishment of the South African Renewable Energy Technology Centre (SARETEC) in the Western Cape.

Studies for the potential of the localisation of wind (DTI 2015), solar PV (Ahfeldt 2013) and CSP industries (SASTELA 2013) have been carried out by various different departments and/or donors and the private sector. Incentives have also been set up or amended to attract renewable energy investment and manufacturing to South Africa (DTI 2013c). Notably the Special Economic Zone (SEZ) act was approved in May 2014 in order to strengthen the current industrial development zone (IDZ) act. SEZs are geographically designated areas for specifically targeted economic activities identified under the IPAP (DTI 2014b). Under the act, manufacturing facilities in an SEZ qualify for financial and other incentives including a reduced corporation tax rate. Of the ten aspiring SEZs in South Africa, the current Atlantis IDZ in the Western Cape has been designated for green technology and currently houses GRI industries' wind tower facility; the Coega IDZ houses DCD wind towers (see Section 7); and the East London IDZ is home to the solar PV manufacturing facility ILB Helios (see Section 8). According to Green Cape, a development agency of the Western Cape government which has been heavily involved in the Atlantis IDZ, the aim of an SEZ is to keep as much of the value chain process in one place by for instance supporting a larger manufacturer that would then allow small, medium and micro enterprises and smaller suppliers to input into the value chain e.g through logistics, transport, nuts and bolts, wiring and supply of personal protective equipment. Ideally this will create economies of scale in various different industries in order to be able to compete with the scale of manufacturing from Asia, particularly China. As wind manufacturer (1) explained [in interview October 2014]: "lots of things are being imported that could be made here by SMEs…We can supply smaller goods that don't need to be tested and can be made in South Africa."

It is difficult to predict the effectiveness of these national commitments to the green economy and localisation in enabling South Africa to set up a local manufacturing industry, develop innovative capabilities and compete with international imports in renewable energy. An evident challenge for the country as a late adopter is to break into increasingly consolidated markets where there is currently a global surplus of technology equipment and a continuing drop in technology costs. Significantly the country does not have a well-established industry for the manufacture of renewable energy equipment (Ahlfeldt 2013:xiv), or indeed manufacturing more generally (Bhorat et al 2014). This is exacerbated by the fact that wind and solar PV industries involve trajectories of increasingly complex technology and are more knowledge than labour intensive (Olsen 2012:138), with greater requirements for semi to highly qualified skills and often internationally mobile labour. Meanwhile, a lack of skills and expertise was identified by a number of interviewees both at blue collar/artisan level (e.g welders and cutters in the case of wind) and white collar. In this sense South Africa is a long way from what Bell and Albu (1999:1730) refer to as the 'international technological frontier', which evokes Eberhard's (2013:6) question over which parts of the value chain it makes sense to localise in the interests of competitiveness and the maximisation of local employment.

As Lall (1993:102) explains, "the need for formal technology imports rises with the sophistication of the technology: some technologies can be mastered relatively easily by only importing equipment; others needs licensing; and others need (or may only be available under) equity participation by the technology suppliers… whatever the choice however the developing country has to invest in skills, R&D, infrastructure and support systems". Such a statement relates to the consideration by an industrial development zone employee [in interview November 2014] of the spatial mobility and volatility of manufacturing: "manufacturing is quick. It comes in and out, like hot money. Europe holds a lot of the intellectual property… South Africa may rather need to look into applying attention to R&D programmes instead of local content requirements."

Further challenges include policy uncertainty, particularly the uncertain status of the lates draft of the country's Integrated Resource Plan for electricity (IRP) (Baker et al 2015) and grid connection problems. Such challenges argue manufacturers, pose a threat to the viability of their projects (Creamer 2014) and has discouraged other foreign technology companies from setting up in South Africa. Connectivity issues caused by a lack of technical and financial capacity within the utility Eskom to connect intermittent and/or variable sources of generation to its transmission grid was a key cause of delays to the announcement of winning projects under round four and to the realisation of the financial close of round three of RE IPPPP. It is anticipate that future rounds will also be affected. These delays have had financial implications for project developers who pass the cost of uncertainty on to the technology manufacturers and in turn to those that supply intermediate inputs and raw materials to the manufacturers. In essence the entire supply chain has been affected. The frustration felt by the industry is captured in a media interview (*ESI-Africa* 2015) with Arturo Herrero, head of strategy at Jinko Solar, who recommends that prospective investors refrain from "investing in South African production until Government provides clarity and Eskom solve their issues".

6. National tensions and local content loop holes

The implementation of local content requirements under RE IPPPP has illustrated key tensions between the realisation of national priorities for employment generation, skills development and increased local manufacturing and on the one hand, and the demands by financial institutions for 'proven technologies' and project 'bankability' on the other. Because of lenders' aversion to risk and their requirements for suppliers with international reputations, local content thresholds increase the risk profile of a project (Baker 2015). Consequently, smaller national players have been precluded from participating in RE IPPPP as technology and energy service providers (Rennkamp & Westin 2013:18). A further constraint to the participation of local companies is the requirement that technologies be certified by the International Electrotechnical Commission. Therefore many small medium and micro enterprises (SMME) have been excluded from the national renewable energy value chain due to the standards of international certification and requirements of project finance. However, the dependence on international suppliers inevitably implies that a major share of capital expenditure and investments are leaving the country by way of purchasing technology hardware from large foreign firms (Moldvay et al 2013:4-9).

There was a general sense that in rounds one and two EPCs could have used more local products and services than they did, but as foreign companies, lacked the relevant knowledge to procure nationally available supplies and so ended up importing them unnecessarily. Similarly, large international technology supply companies are often bound by their own internal guarantees and are therefore obliged to deploy their own personnel and materials from abroad rather than sourcing locally. While there are national attempts to overcome such restrictions, for instance the South African Renewable Energy Technology Centre plans to train service technicians on how to fix cracks in blades [in interview, December 2014] it is not clear whether this will satisfy the demands of international company warranties. Safety issues were also identified as a constraint. For example, according renewable industry member (4) [in interview November 2014] "for a 75 MW solar farm, local electrical contractors do not have the resources to carry the risk of something going wrong in terms of failure to deliver on time and at the right quantity, therefore the REIPPPP has largely excluded SMME participation". However according to some interviewees, large international electrical contractors such as ABB and Schneider are increasingly starting to subcontract to local companies.

Further tensions were attributed to ideological differences between government departments, most evidently between the DoE backed by National Treasury and the Department of Trade and Industry (DTI). These tensions have been reflected in and exacerbated by the lack of clarity and inconsistency over local content regulations. In brief, National Treasury places more emphasis on least cost and assumes that locally manufactured goods are more expensive than imported goods. Therefore if local content requirements are too high then the price of the project will not be competitive. The DTI meanwhile prioritises the incentivisation of local manufacturing and associated job creation, and argues that in addition to cost, various factors such as the type of technology, the technological component in question and the scale at which it is manufactured or imported must be taken into account. While the DTI is responsible for drafting the local content requirements, the RE IPPPP process is ultimately governed by the Treasury supported IPP-unit (Eberhard et al 2014). Treasury therefore appears to hold the greater sway over how the economic criteria are defined.

The lack of clarity over local content rules and definitions has meant that they have been interpreted quite differently by various different project developers and EPC companies (Ahlfeldt 2013:8). This lack of clarity has also enabled project developers, particularly of solar PV, to exploit and manipulate loop holes (Forder 2014), discussed in greater detail in Section 8. A number of industry members concurred that it has been possible for project developers to game the system by being 'creative'. One project developer [interviewed in November 2013] stated that "The RE IPPPP process has got built in contradictions that make meeting local content requirements difficult, and the policing of local content where it could be possible is inadequate". Consequently requirements can and have been met by back door methods and box ticking exercises. These loopholes may also in part be due to a lack of understanding by policy makers of the nature of renewable energy technology supply chains and production processes, which will have inevitably posed a challenge to defining local content requirements that work effectively. As PV manufacturer (1) explained [in interview October 2013] "we need much clearer definition of what local content should mean and what a locally produced module should mean… putting screws into something shouldn't count as locally manufactured".

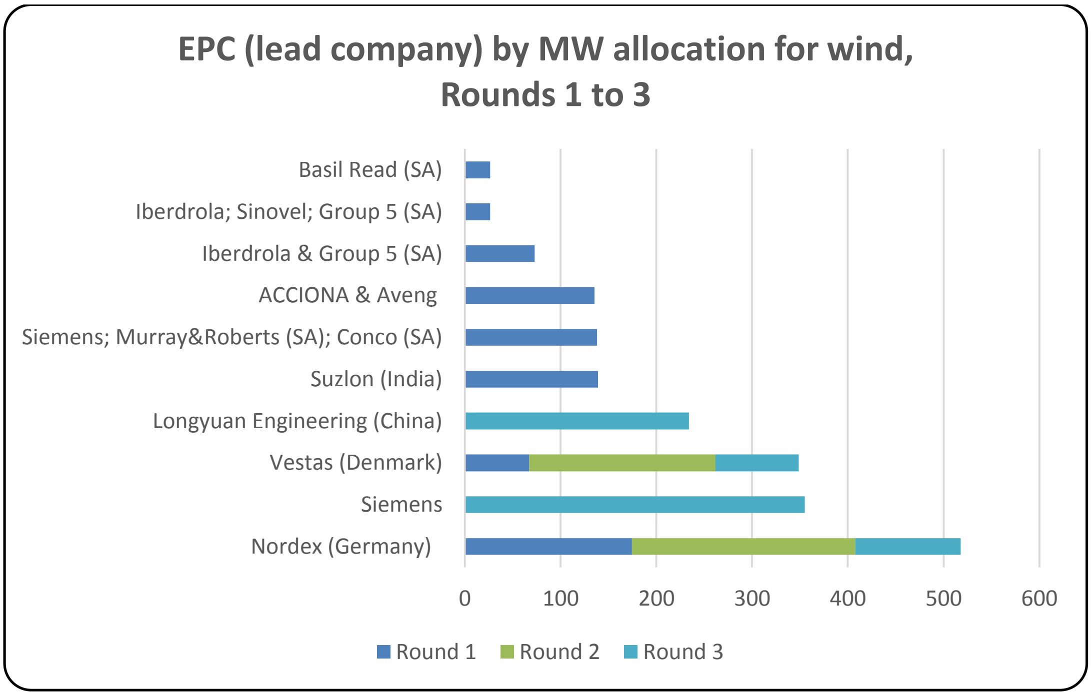
In order to prevent further manipulation of local content requirements by developers and under pressure from manufacturers, it is understood that the DTI attempted to refine the rules so that installation or balance of plant must constitute a certain percentage of local content and the technology also. Wind industry (3) explained [in interview, October 2014]: "to split the target as a percentage of balance of plant and wind turbine is a clear and obvious step to understand what we are getting out of local content". However when the bid documents were released for round four in mid-2014, this did not materialise: "Everyone expected that for round four Treasury would issue a clarification note by component that said for instance wind towers 30 per cent, blades 10 per cent...but the bid documents are released and then there is no clarification note" [renewable industry member (3), in interview, December 2014].

A further issue is how South Africa's local content requirements align or conflict with international trade rules and agreements. This is a battle likely to be fought in light of an emerging trend of tit for tat trade and import disputes between various countries, including US, EU, India, China, Japan and Canada (Lewis 2014a,b, Curran 2015). As Lewis (2014a:11) explains: "there is a fundamental conflict between the political economy of domestic renewable energy support and the basic principles of global trade regimes". However while international trade explicitly prohibits differential support to domestic over foreign technology thus far, there has been limited legal precedent to challenge this (Ibid p13). Questions of trade are now discussed in the following sections in relation to wind and solar PV.

7. Wind

The increasingly protectionist nature of the global wind industry (Lewis 2014b:515) with fewer and larger players that are constantly undergoing mergers and acquisitions[6] may restrict the ability of South Africa to engage in technological innovation, particularly at commercial scale. While there have been small-scale successes and failures in setting up a national manufacturing industry for wind, discussed below, engineering procurement and construction (EPC) companies involved in wind energy projects under RE IPPPP are dominated by global leaders (see Figure 2). Reflecting the relatively vertically integrated nature of the global wind technology industry and its supply chain, the EPC contractor is often the same company as the original equipment manufacturer (OEM), who supplies technology to the projects and in many cases is then granted the contract for operation and maintenance. Such companies hold the warrantees and international experience that are deemed to reduce risk under the norms of project finance (Baker 2015). While European companies still dominate in the EPC and technology supply, a significant minority of emerging market companies play a role, including India's Suzlon and China's Sinovel[7] in round one of RE IPPPP and China's Guodian United Power in round three (see Figure 2). In round four China's Goldwind is undertaking the EPC for two projects being developed by South African company Biotherm Energy Ltd, reflecting the growing international presence of Chinese companies outside of their domestic market as the world's largest installers of wind capacity, now holding 21 per cent of market share (Lewis 2014a:23) having overtaken the first movers of Germany and the US in 2010 (Lema et al 2013:46).

Figure 2[8]



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[6] Recent examples include the sale of Acciona to Nordex (Lee 2015) and the purchase of UK company, Blade Dynamics by GE (Weston 2015).

[7] Suzlon was to have held a market larger share but lost an EPC contract to Nordex at the last minute due to concerns of financial solvency

[8] Figures 2 and 3 reflect the author's own compilation from publicly available sources at the time of writing. The figures do not reflect all shareholders involved in the JVs or consortiums carrying out the EPC.

Localisation of wind can take a variety of forms (Lewis and Wiser 2007:1845) including: the assembly of imported parts; manufacture of some components or entire turbines; local technology development through innovation and R&D carried out by a domestic firm often in combination with domestic research organisations; and technology transfer from an overseas firm via a licensing agreement which may or may not include the transfer of technological 'know how'. However, there will be stiff competition from leading manufacturers with strong international reputations, decades of experience, financial backing from mega-corporations such as GE and Siemens and an ability to ffer multi-year service warranties that reduce investment risk and attract favourable terms (Lewis and Wiser 2007:1844). The potential for South Africa to develop a local industry may also be restricted by limited incentives for leading wind turbine manufacturers to license information to a company that could in turn become a competitor and, if in a developing country, more likely to benefit from cheaper labour (Ibid p1847).

While the construction and maintenance of most components of a wind turbine such as blades, gearboxes and power converters (Lema et al 2013:44) require semi to highly specialised expertise, the skill level required for tower manufacture is more at the level of artisan as it does not involve highly sophisticated technology. Furthermore due to its size and weight the tower is the most expensive and logistically challenging to import and transport. As previously discussed, in the first round of RE IPPPP the local content requirement was 25 per cent (see Table 2) which meant that meeting the balance of plant locally was sufficient reach the target and all wind towers were imported. Under rounds two and three having a locally manufactured wind tower was sufficient to meet local content requirements as the tower takes up approximately 12-14 per cent of the project cost [turbine manufacturer in interview October 2014]. By round four and beyond all towers will need to be manufactured in country.

Consequently, two wind tower manufacturing plants were recently set up in South Africa, one run by GRI industries[9], a subsidiary of Spanish Cooperación Gestamp, in the Atlantis SEZ and the other by DCD wind towers[10] in the Coega Industrial Development Zone near Port Elizabeth. Spanish company Acciona has also established concrete tower making facilities on its project site for the Gouda wind farm in the Western Cape. Both GRI and DCD manufacture towers for OEMs e.g Nordex, Vestas from where the equipment is sourced. The OEMs in turn sell the hardware to the project developer. Manufacturing is done under a non-disclosure agreement with the OEM whereby the company undertakes only to manufacture and has no involvement in design, which may therefore restrict opportunities for innovation spill overs. Of note is that because different OEMs have different designs, skills acquired from working on one tower will not necessarily be transferrable.

[9] Construction of the factory started in March 2014. The plant is owned 100 per cent by GRI and unlike DCD wind towers is not supported by South Africa's Industrial Development Corporation (IDC). The GRI factory is situated in the recently established Atlantis SEZ for which it is considered the anchor project. It received significant assistance from the City of Cape Town via Green Cape which sped up the process of securing relevant permits and other requirements e.g receiving an environmental impact assessment and zoning the land. The factory's location, 40 km from Cape Town's port and 80km from Saldanha port, will facilitate the import of raw material and is potentially strategic should the company then seek to move into supplying export markets at a later stage.

[10] The DCD wind tower factory has been operation since February 2014 with the first tower built in September 2014. Factory ownership is split between the DCD Group, the Industrial Development Corporation (IDC) and the Coega Development Corporation (CDC). DCD restarted the work initiated by Isivunguvungu Wind Energy Converter (Pty.) which closed down in 2012 (see below). DCD is undertaking two contracts, one for Vestas and the other for Nordex.

The OEMs have an approved list of which suppliers the factory can buy from which need to conform to the OEM's quality standards and specifications.

All other wind technology components for supply for projects under RE IPPPP are currently imported. With the exception of Adventure Power, discussed below, which makes small-scale blades, there are no utility-scale blade manufacturing facilities in South Africa and this is not currently anticipated. Given that all global OEMs have their own blade designs of their own and have several different designs each, significant market certainty would be needed for any blade manufacturer to set up in South Africa. According to a member of the South African Wind Energy Association, South Africa's market "can probably only support one turbine manufacturer" [in interview, October 2014]. OEMs such as Vestas and Nordex usually outsource blade manufacturing to specialised companies such as LM Blades, a large international manufacturer of blades for various different companies headquartered in Denmark. LM Blades was considering setting up a blade mould factory in South Africa and according to renewable industry member (2) [in interview, December 2014] "was but a signature away". However the company's plans were shelved following the uncertainty created by the reduction of the wind allocation in the revised IRP, discussed in Section 5. As government (1) stated [in interview, January 2015] "companies that will have put in an investment based on the projections of the IRP 2010 are now holding back until we get an approval of the revised IRP."

i) I-WEC: early failures

An early attempt to set up a national wind manufacturing company in anticipation of RE IPPPP failed because it was unable to meet bankability criteria and two years' of experience required under RE IPPPP's project finance. Cape Town-based Isivunguvungu Wind Energy Converter (Pty.) Ltd (I-WEC) was set up in 2009 in the Western Cape. The company imported a blade mould made by in China by Swiss company Gurit under licence from the German developer Aerodyn (Maritz 2011). The company set out to manufacture "state-of-the-art 2.5MW wind energy turbines and rotor blades in South Africa for the growing local markets" (Rennkamp and Westin 2013:18) with an estimated 65 per cent local content. However I-WEC folded in 2012, because as wind industry (2) explained: "Ultimately you have to be able to produce a blade that works with a turbine and that is certified with that turbine because otherwise the whole 'wrapped guarantee' thing falls through and that is what IWEC wasn't able to do. They couldn't provide a parent company guarantee that would satisfy the banks."

ii) Adventure Power: small-scale success

Beyond the utility-scale market set up under RE IPPPP there is one South African wind turbine manufacturer, based in East London in the Eastern Cape. A 'proudly South African'[11] company, Adventure Power manufacturers 300 KW wind turbines which are much smaller than the utility-scale turbines deployed in RE IPPPP projects. The turbines are 'fourth generation PMG' meaning that they use magnets and direct drive and there is no gear box. The company has been engaging with Chinese expertise and uses some Chinese manufacturing equipment in their manufacturing process, such as magnet energisers. The company also has a purchasing office in China. With the exception of imported magnets, the turbines are manufactured locally and were certified by DNV/GL in

[11] This term is inspired by a 'buy local' campaign launched in 2001 by government, organised business, organised labour and community organisations to boost job creation and pride in South African companies and national products and services. See: http://www.proudlysa.co.za/Index.aspx

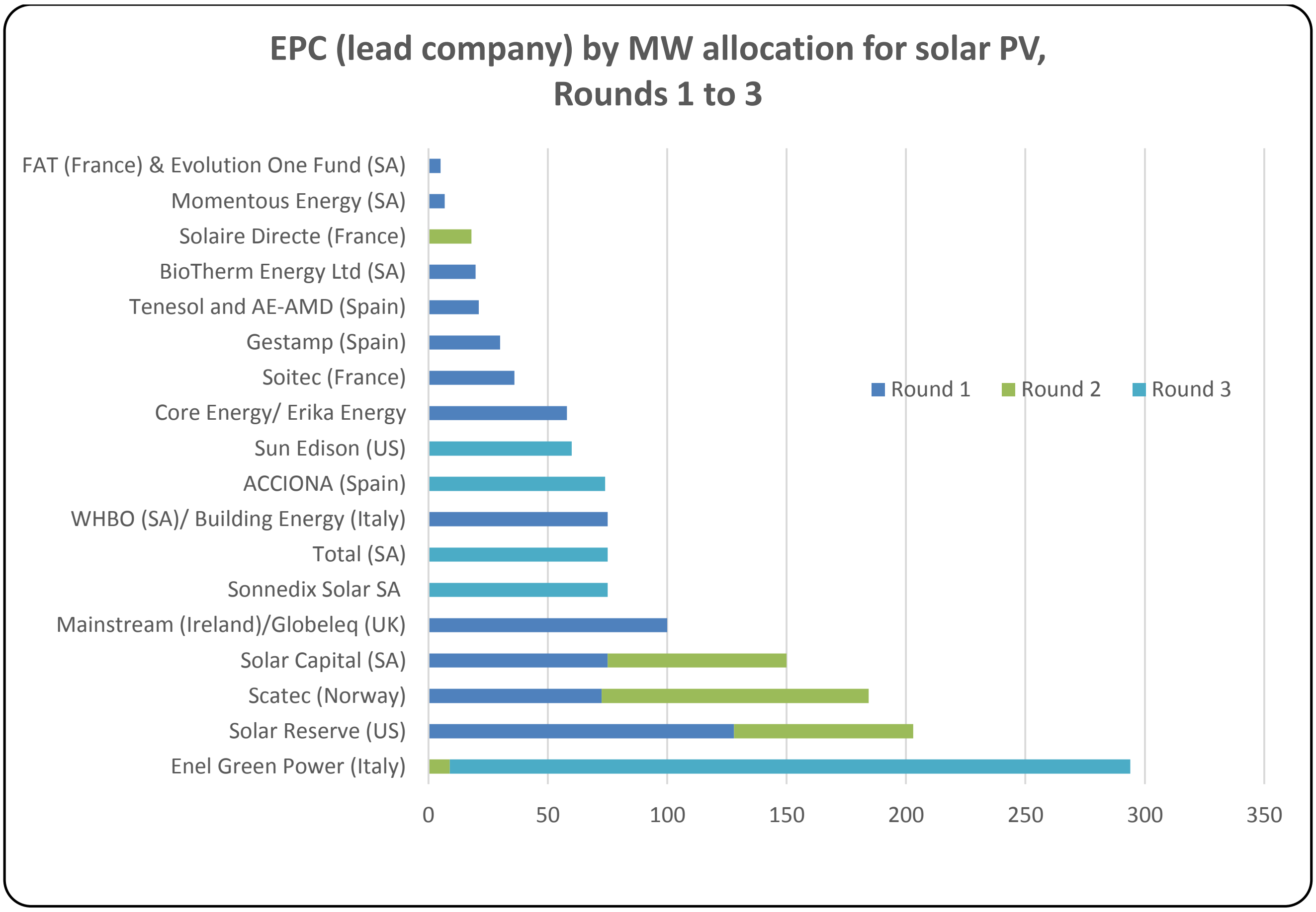
December 2013. Adventure Power's turbines are too small for deployment at commercial scale and are considered 'high risk' by investors and financiers involved in RE IPPPP. However the turbines now generate electricity for Adventure Power's sister factory, an automotive component manufacturer, in Uitenhage and East London. Furthermore, the company is now being supported by the DTI to develop a pilot wind farm comprising six wind turbine generators, within the East London IDZ, which it is anticipated will provide a reference for both domestic and international markets.

8. Solar PV

Unlike the wind industry, the EPC for solar PV is less often involved in technology supply given the more dispersed nature of the supply chain and the components involved e.g panels, frames, inverters, transformers, tracking system, cable trays, cells, glass. There is also greater potential for innovation in solar PV than wind, given that wind is more mature as a technology and therefore harder to break into (Rennkamp and Boyd 2013:12). While the revised draft of the IRP (see Section 5) has increased the allocation for solar PV, providing a potentially positive signal for the industry, a number of solar PV manufacturers argued that the allocation of approximately 600 MW for solar PV within each round of RE IPPPP has been insufficient to encourage the development of a local industry.

While the EPC for solar PV is dominated by European and US companies (see Figure 3), Chinese companies play a significant role in technology supply, reflecting China's export driven industry and its role as the world's largest manufacturer of solar PV technology, having overtaken Germany as the original global market leader in 2008 (Dunford et al 2013:30). According to Dunford et al (2013:31) solar PV cells and modules made by Chinese manufacturers cost about 50 per cent less than those provided by Germany. Not only has this contributed to global dramatic tariff reductions as witnessed in South Africa's case between Rounds 1 and 4 of RE IPPPP, but also been the source of significant international conflict and resulted in anti-dumping legislation in the EU and US, as discussed in Section 8.ii. While Chinese firms dominate the manufacturing of solar panels, other parts of the value chain are dominated by EU, US and Japanese companies (Curran 2015:11).

Figure 3[12]



Chinese Solar PV technology hardware deployed in South Africa is either provided directly by state-backed or state-owned Chinese companies with cheap access to capital and strong financial support from government (Ahlfeldt 2013:11) or by companies headquartered elsewhere but who source from China where the hardware is made under licence (Dunford et al 2013:30). Chinese solar PV manufacturers supplying to projects under RE IPPPP include Suntech,[13] Yingli Solar, Trina Solar, Jinko solar, Build Your Own Dreams and Renesola. While many of these companies are now integrated into global financial markets and listed on the New York Stock Exchange and/or the NASDAQ, in recent years a number of them such as Yingli and Trina have run into high levels of debt (Publicover and Lee 2015). Meanwhile, the supply of inverters is dominated by the German company SMA Solar which opened an inverter factory in Cape Town in December 2014. Many of the mounting structures are provided by Schletter, also German.

[12] Figures 2 and 3 reflect the author's own compilation from publicly available sources at the time of writing. The figures do not reflect all shareholders involved in the JVs or consortiums carrying out the EPC.
[13] Once the world's largest solar PV equipment maker; following its collapse in 2013, Suntech was bought by Chinese company, Shunfeng Photovoltaic International (UNEP/BNEF 2014:78).

Table 3: manufacturing/ assembly plants for solar PV in South Africa[14]

Company	Technology Type	Location	Annual Output	Ownership	Finance	Opened	Comments
Solaire Directe Southern Africa (SA)	Solar PV (modules, wafers invertors and other)	Belville, Cape Town	80 MW per year (verify)	French/SA JV, subsidiary of the Solairedirect Group, the largest private power producer in France.	Unknown	2009	Chinese company ReneSola ltd has a tolling agreement with Solaire Directe SA.
Art Solar	Solar PV modules	Durban, KZN	40 MW per year	South African owned by private shareholders.	Unknown	2013	The technology has been provided by Swiss and German equipment manufacturers.
ILB Helios Southern Africa	Monocrystalline & polycrystalline panels. Lamination in factory	East London Industrial Development Zone	120 MW	Subsidiary of Spanish worker's cooperative, Mondragón, largest PV manufacturer in Spain.	IDC provides 50% of debt and 17% equity. An IDC-financed worker's cooperative holds 10% equity	2014	The plant laminates its panels using German laminators. It is also a distribution hub for panels made in China by ILB Helios.
Jinko Solar	Solar PV modules. Lamination in factory	Belville, Cape Town	120 MW	JinkoSolar Holdings Co., Ltd	Unknown	2014	Jinko's first manufacturing plant outside China.
Sunpower	Solar PV panels	Cape Town	160 MW	Unknown	Unknown		A French company that took over the Tenesol group based in Western Cape. Sunpower are developers, manufacturers, EPC and IPP.
Suntech	Storage warehouse for modules	Cape Town	Up to 500 KW (storage only)	Wuxi Suntech Power Co	Suntech is owned by Shunfeng Clean Energy (SFCE)	2014	Suntech is awaiting clarity on LCRs before setting up manufacturing facility in Cape Town.
SMA solar	inverters	Cape Town		SMA solar		2014	

[14] Authors' own compilation based on interview data and publicly available information

i) Transfer pricing

The ability of many solar PV developers to sidestep local content rules through 'transfer pricing' (Forder 2014) under RE IPPPP is a further challenge to South Africa's ability to develop indigenous capabilities. Under transfer pricing, a foreign component supplier sets up a local company and imports technological hardware. The price of that hardware is then marked up and sold on to the developer. That mark-up constitutes local content. Transfer pricing has been possible because, as described in Section 4, local content is measured in financial spend. As renewable industry member (1) described [in interview November 2013]: "…companies like Enel[15] were able to screw the industry by marking down the cost of foreign technology tremendously, importing it and then marking it up in the local company and calling it local content. What they have done isn't legally wrong it is just ethically wrong." For this reason the South African Bureau of Standards have warned of products being labelled as 'made in South Africa' while they are in fact merely assembled in the country, with more than 90 per cent of foreign content (DTI 2014a).

According to the South African Renewable Energy Council, transfer pricing has meant that solar PV module manufacturers in South Africa that were set up with the aim of supplying to projects approved under RE IPPPP (see Table 4), have had less than two per cent of their production capacity taken up by local orders. Consequently they have either started to seek foreign markets (Creamer 2014) via 'toll manufacturing', as discussed below or have refrained from setting up a manufacturing plant in South Africa as Trina Solar, one of the top PV manufacturers in China, has done (Creamer 2015). In other cases, manufacturing/ assembly plants also serve as distribution hubs for panels made in China either by their company or a Chinese client. For instance Suntech has set up a storage warehouse in order to increase its sales capacity to both the South African and African market and eliminate some of the transaction costs involved in the shipping and import of PV modules.

One solution put forward by the South African solar PV industry association (SAPVIA) and other stakeholders in order to prevent transfer pricing is that that the module be assembled, framed and most significantly *laminated* in South Africa. As DTI [in interview January 2015] explained, lamination would mean that people cannot just bring in "fully imported panels, pack them in boxes and claim local content for paying people who are packing things in boxes. Lamination seems like a benchmark, because then you would have to string the cells, laminate, put in glass, a frame, a junction box and then you have a panel. That is basically the assembly process." While investing in the machines that do this is expensive, it is argued that such an investment will result in job creation and spin off activities. In one example ILB Helios is already carrying out lamination at their factory in the East London Industrial Development Zone. Renewable industry member (2) stated [in interview December 2014] "the biggest and easiest thing that was anticipated from the local content regulations for round four was the requirement that modules be laminated in South Africa. This would mean that these four or five factories would have had so much work that they would have been booked up for the next 12-18 months... This didn't happen." The fact that lamination was not included in the bidding requirement for round 4 is perhaps an illustration of National Treasury's power over the bidding process for RE IPPPP and final definitions of the economic development

[15] Enel Green Power (EGP) is an Italian company that as lead developer has won 1110 MW of solar PV projects under Rounds 1 to 4. These projects use thin film modules manufactured by 3Sun, of which EGP is now the sole owner.

criteria, as discussed in Section 6. It is now anticipated that lamination will be introduced from round five onwards but there was no publicly available information on this at the time of writing.

ii) Anti-dumping and toll manufacturing

The EU-China solar dispute, which "represents the most significant anti-dumping complaint the European Commission has ever investigated" (Lewis 2014:24) has had far reaching impacts, including in South Africa. Anti-dumping duties were imposed by the European Commission on imports of solar PV crystalline silicon modules and cells originating in or consigned from China in December 2013 (Hopson 2015), applicable until December 2015. Measures include minimum pricing and a quota system (Curran 2015:3). As a result of transfer pricing, in addition to delays in the bidding process discussed above, a number of plants in South Africa have resorted to 'toll manufacturing' on behalf of Chinese manufacturers. Toll manufacturing sees Chinese suppliers sending component parts (frames, glass, cells etc) to South African companies who assemble the product which the Chinese company then sells on to European developers. Because the product has been assembled in South Africa, the Chinese company has thus far evaded anti-dumping legislation. Similar to other cases documented by Lewis (2014:17) this illustrates the ability of Chinese manufacturers to reconfigure their supply chains in order to evade duties on imports to Europe and the US and the ability of GPNs to adjust their structures in response to trade restrictions (Curran 2015). This instance of toll manufacture adds to studies on the striking differences between the geography of use and the geography of manufacture which Dunford et al (2013) have explored in the case of Germany and China (see also Lewis 2014:23)

9. Conclusion

This paper forms an early empirical contribution to the emerging theme of renewable energy technology capabilities in South Africa and a rich description of the emerging industry. It demonstrates how technology development in the country's wind and solar PV industries has been shaped by the interaction of territorially embedded factors with international dynamics. Such dynamics include: the geographically dispersed nature of global supply chains and production networks in renewable energy; the determination that finance and investment has over technology and innovation pathways; the rise of emerging market companies, particularly China in renewable energy manufacturing; and trade disputes. I now conclude with the following reflections.

RE IPPPP is a national success story and an international example for a programme that has facilitated the very rapid take off of a utility-scale renewable energy industry by IPPs within an otherwise coal-fired, crisis-ridden, monopoly electricity sector. However, there are concerns over the extent to which the potentially progressive economic development criteria will be realised. Specifically, the extent to which they will result in a new industrial base and new areas of technological capability, or instead generate short-term imported skills for complex, sophisticated technologies. In analytical terms this relates to Lall's (1993:103) caution that, "until host countries achieve fairly high levels of development, transnationals tend to transfer the results of their R&D rather than the innovative process itself" and Bell and Albu's (1999) assertion that systems of knowledge accumulation and R&D are equally important as production.

Relating to the theme of competitive dynamics within GPNs (Coe and Yeung 2015), dominant international firms in renewable energy manufacturing and technology supply are competing with each other in an attempt to reinforce their market power in South Africa. There is a complexity of relationships and networks between national and international institutions involved in technology supply, EPC contracts and manufacturing plants. South Africa's emerging renewable energy technology market has a strong and inevitable dependence on global industries, which in turn pose a key challenge to the country's ability to facilitate a national manufacturing industry with long-term ownership and innovative potential. This begs the question therefore, as to whether South African firms, as relative latecomers, will be able to develop their own comparative advantage in the face of such stiff competition.

This paper has further added to two emerging themes in the GPN literature: finance (Coe 2014) and technological development in renewable energy (Dunford et al 2013), and the powerful determination that the former has over the latter. Clear tensions also exist between bankability and economic development criteria specific to the South African context. In the absence of a well-established industry for renewable energy manufacture in South Africa, local content thresholds increase the risk profile of a project. And because of the risk aversion of lenders, their demands for 'proven technologies' and companies with international reputations, smaller, national players have been precluded from participating in RE IPPPP as technology suppliers and/or service providers. For this reason, national companies such as I-WEC and Adventure Power, discussed in Section 7 have had limited success in breaking into an increasingly competitive, utility-scale market dominated by international companies. In the case of Adventure Power however, opportunities for national innovation may lie in smaller scale options and this remains an avenue for further research.

From the perspective of GPNs, the paper further illustrates the geographic differentiation of renewable energy technology manufacturing and that of deployment (Dunford et al 2013). For example in the case of solar PV, technological components are on the one hand exported via toll manufacturing agreements, and on the other, imported through the use of transfer pricing in order to avoid the costs associated with local manufacture. While transfer pricing, as a significant market distortion threatens the sustainability of local manufacturers, the practise of toll manufacture illustrates the transient nature of manufacturing/assembly plants being set up in South Africa given that for the most part, the technology hardware in question is still owned by international companies. Such findings also reflect the global nature of capital and the subsequent vulnerability of labour as 'spatially trapped' (Coe et al 2004:472) when compared to the international mobility of production and relate to Moldvay et al's (2013) claim that rather than being retained and reinvested into the local or national economy, finance is likely to leave the country though the purchase of technology hardware from foreign firms.

Finally, a number of uncertainties remain, many of which depend on future dynamics yet to be determined. Firstly, at the international level, developments in renewable energy technology markets will inevitably affect how South Africa's own industry evolves. These developments include the on-going trade dispute over Chinese solar PV panels, which combined with domestic factors have had a significant influence over the activities of the country's solar PV manufacturers. Secondly how upcoming rounds of RE IPPPP may develop is also significant. For instance, despite the promising commitment by government for the procurement of a further 6300 MW, previous delays due to grid connection issues and policy uncertainty particularly over the revised draft of the IRP have curtailed the interest of foreign manufacturers such as LM Blades. Thirdly, the extent to which local content requirements and related innovation and industrial policy will be redefined and enforced to ensure a more meaningful adherence to local production and the development of national capabilities is as yet unclear, but remains a crucial area for the long-term success of South Africa's emerging industry.

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