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The political economy of technological capabilities and global production networks in South Africa's wind and solar photovoltaic (PV) industries



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ABSTRACT

We examine underlying conflicts between technological capabilities and global production networks in South Africa's solar photovoltaic (PV) and wind energy industries. This includes an analysis of the complex and multi-scalar relationships that exist between international and local institutions, as well as the embedded nature of renewable energy technology within a national and international political economy. In South Africa's case, this encompasses endogenous factors such as the introduction of a regulatory framework for renewable energy independent power producers as well as international dynamics such as rapidly evolving trends in renewable energy investment, trade, and technology development. While South Africa's wind and solar industries have been celebrated internationally, tensions exist within national government between commercial priorities and requirements for economic development including local content. We provide an empirically rich description to explore how competition and manipulation have posed obstacles to the localisation of renewable energy technologies at the national level.

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Introduction

South Africa's utility-scale, renewable electricity from independent power producers now constitutes a small but significant source of generation alongside its coal-fired, crisis-ridden state-owned monopoly electricity utility Eskom.¹ While a number of studies have explored the policies and politics behind the implementation of a renewable electricity generation sector, (e.g. Eberhard, Kolker, & Leigland, 2014; Baker, 2016), we expand that focus to examine the significant challenges that exist to the creation of national technological capabilities in renewable energy. Drawing from literature spanning innovation studies, development policy, and geography, we ask: what is the political economy of technological development in solar photovoltaics (PV) and wind in South Africa? What does this tell us about technological capabilities as

well as emerging international trends?

While the country's renewable electricity industry has been celebrated internationally (Dodds, 2014), tensions exist between commercial priorities and requirements for economic development including local content. Such tensions can be found within national government between the demands for least cost technology, and national priorities for the establishment of a local manufacturing industry and job creation; and between global production networks (GPNs) for solar PV and wind technologies and national local content requirements. Consequently we explore how competition and manipulation within GPNs have posed obstacles to the realisation of the localisation of renewable energy technologies at the national level. Our analysis separates the experiences of wind and solar PV given that while both industries are increasingly competitive, there are significant variations that exist between them in terms of their GPNs and technological capabilities.

Our analytical approach is informed by the literature on technological capabilities (Bell, 2009) and global production networks (GPNs) (Coe, 2012). Together these literature facilitate an analysis of the complex and multi-scalar relationships that exist between international and indigenous institutions and the embedded nature

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¹ Between 2014 and 2015 the country faced its worst electricity crisis for 40 years.

of technology within a national and international political economy. In South Africa's case this political economy includes endogenous factors such as the introduction of a regulatory framework for renewable energy independent power producers, and international dynamics such as rapidly evolving trends in renewable energy investment and technology development. While these literature are rarely linked, we argue that there is particular relevance for doing so. Firstly because of the GPN literature's recent engagement with renewable energy technologies (Curran, 2015), and secondly given the influence that GPNs can have over the realisation of technological capabilities at the national or even international level, through for example intellectual property restrictions, access to capital, or standards.

This paper also draws from and contributes to 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, Johnson, & Engelmeier, 2014; Lema, Berger, & Schmitz, 2012; Fu & Zhang, 2011), green industrial policy in developed countries (Pegels & Lütkenhorst, 2014), and comparisons between the two, for example China and Germany (Dunford, Lee, Liu, & Yeung, 2013). Moreover, limited consideration has thus far been dedicated to South Africa with exceptions being Rennkamp and Boyd (2013), and Mulcahy (2012) given the recent emergence of the industry. The findings of this paper therefore may have important policy implications for other non-OECD countries in the sub-Saharan African continent and elsewhere which have recently embarked, or are about to embark, on programmes for the deployment of utility-scale electricity generation from renewable energy, for instance Tanzania, Namibia, Mexico and Uruguay.

Our paper's primary source of data is field work undertaken between 2013 and 2015 (Baker, 2015; Baker, Burton, Godinho, & Trollip, 2015). This includes 47 semi-structured research interviews with members of the renewable energy industry, government departments, the electricity utility, the financial sector, civil society and labour in South Africa (see Annex 1). The field work also involved 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.

As a secondary method, we also draw 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 the country's renewable energy independent power producers' procurement programme, the RE IPPPP, are not available in the public domain. For this reason we 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.

The paper's structure is as follows. Firstly we outline our analytical framework before setting out the national context from which the country's renewable electricity generation sector has emerged. We then consider the national measures and systems that exist for the support of technological capabilities in renewable energy. We proceed to explore how tensions between the two concepts of global production networks and technological capabilities play out within the South African context, which together with the themes of competition and manipulation, are further illustrated with two case studies of wind and solar PV.

Linking technological capabilities and global production networks

Our analytical framework draws from two literature which though related, are rarely combined: technological capabilities and global production networks. In tandem, such concepts—one emphasising the nature of indigenous technological development and innovation, the other the interlinkages between local, national, and international supply chains—enable us to reveal the networks of firms and institutions participating in South Africa's renewable energy sector. We maintain that together these concepts offer a more nuanced and complete picture of the political economy of technological development and allow us to consider dimensions such as the distribution of power within those networks (Bridge, 2008); the significance of skills development (Lall, 1993); the role of trade and the deepening international division of labour across global value chains (Curran, 2015); and broader political, socio-cultural, and environmental implications resulting from these trends (Coe, Dicken, & Hess, 2008; Gereffi et al., 2005).

Acknowledging the diversity of literature on technological capabilities, Bell and Pavitt (1993) define this concept as a spectrum that spans from 'production capabilities' to advanced 'innovation capabilities'. While the former refers to the operation and maintenance of existing products and processes, the latter refers to the ability to innovate to the extent of developing new products and processes. Consequently, Bell and Albu (1999:1717) argue that 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 know-how necessary to reproduce technology hardware (Lema, Iizuka, & Walz, 2015). This is particularly the case in the international solar PV and wind industries which are growing in technical complexity.

The case of South Africa illustrates concepts central to technological capabilities, including the nature of technology transfer to developing countries and related definitions of research and development (R&D); knowledge spill-overs and knowledge leakage (Bell & Pavitt, 1993); industry clusters and innovation systems (Bell & 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., 2012:40). Our study also illustrates long-standing debates over the relationship between imported technology and indigenous technological development in low and middle income countries (Lall, 1993, 1987). This includes the difficulties of transplanting foreign technology into a country where adapted institutions have not evolved jointly, resulting in serious incongruities and disruptions (Mokyr, 1998). Byrne et al.'s (2011:29) discussion on the increasing 'knowledge embeddedness' of energy technologies and the requirement for increasingly specialised technical knowledge are similarly relevant. As Schmidt and Huenteler (2016) point out, while there has been significant renewable energy technology diffusion in non-OECD countries, the ability of such countries to successfully implement industry localisation beyond the point of installation, and operation and maintenance is much less evident

and more research is therefore needed here. Finally such themes link to ongoing 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 & Mallett, 2013).

We engage the concept of GPNs 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. As a challenge to the related perspectives of Global Value Chains (Gereffi et al., 2005) and Global Commodity Chains (Bair, 2005) which tend to make linear assumptions about the nature of production systems (Henderson et al., 2002), the GPN approach is concerned with the 'structural and relational' (Coe et al., 2008) nature of the multi-scalar network configurations that exist between the local and the global, and assumes governance arrangements as complex. Significant for our study, such an approach allows for an analysis of interactions between local actors and production networks at various geographical sites and scales. Above and beyond a focus on the firm, often common in the technological capabilities literature, the GPN approach also encourages a focus on institutions such as government agencies, trade unions, civil society and multi-lateral agencies, and the territories within which they are embedded (Coe, 2012). The GPN's concern with the interconnectedness and uneven development of the global economy and power relations within global relationships (Chester & Newman, 2014; Coe & Yeung, 2015) is similarly poignant.

However 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 Zhang (2013) on China's PV industry, and Curran (2015) on trade policy and the solar PV industry. We also speak to a number of gaps that have been identified within the GPN literature, including an analysis of the role of finance (Coe et al., 2014), considerations of competitive dynamics (Coe & Yeung, 2015), greater consideration of the political economy of trade, development and geographical interdependence (Dunford et al., 2013:16), and the need to better understand the role of Chinese firms on GPN dynamics (Curran, 2015).

While there is limited explicit concern within GPNs for technological capabilities and innovation, with exceptions including (Ernst & Kim, 2002), a better understanding of the role of GPNs can offer a powerful explanation for factors that may assist with or prevent the realisation of technological capabilities at the national level. With this in mind, one of the central concerns of this paper is the key tensions that exist 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 project 'bankability' on the other. However, before exploring tensions between these two concepts in section 4, we firstly establish the national context for the emergence of South Africa's renewable energy industry.

A regulatory framework for renewable energy

With a "highly energy intensive economy" compared to its neighbours (Hancock, 2015), South Africa's economic development has been characterised by its 'minerals-energy complex' (Fine & Rustonjee, 1996) with a historical core based on cheap energy and cheap labour for mining and related minerals beneficiation. With high levels of poverty and inequality, to which energy access is no exception (Sovacool & Rafey, 2011; Baker, 2014) South Africa's monopoly electricity utility Eskom, which supplies 90 per cent of the country's coal-fired electricity and accounts for 45 per cent of

national emissions, is now debt and crisis ridden. Furthermore, despite the continued significance of coal to the country's electricity supply, in 2009 the government committed to reduce the country's greenhouse gas emissions by 42 percent below business as usual by 2025 (RSA, 2015). The country's economic dependence on its energy intensive industries is also subject to shifts and financial and business services now account for 24 per cent of GDP (Bhorat, Hirsch, Kanbur, & Ncube, 2014).

Changes in the country's economic growth path have been paralleled by notable shifts in energy policy. Firstly various stalled attempts in recent decades to introduce both independently procured power and renewable energy eventually culminated in significant national developments for the introduction of renewable energy into the country's monopoly controlled coal-fired grid. Notably in May 2011 the Department of Energy 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 the Renewable Energy Independent Power Producers' Procurement Programme (RE IPPPP) in 2011 (Baker & Wlokas, 2015). The country has since become a leading destination for renewable energy investment. Since mid-2015 a number of solar PV projects have 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). Under the first four bidding rounds of RE IPPPP, 13 GW of capacity has now been allocated, of which 92 projects amounting to 6.3 GW contracted. Of this 3346 megawatts (MW) is for wind and 2297 MW for solar PV, reasons for selecting these two technologies in this study. As of September 2016, 42 projects with a total capacity of approximately 2 GW had been connected to the grid, constituting approximately 2.4 per cent of supply.

South Africa's procurement programme is unique in that the projects in question must structure local communities into their equity share as well as contribute to economic development criteria, including local content as a key focus of this paper. These criteria, which align with the country's 'broad based black economic empowerment' legislation, are a key part of government commitments to the green economy and a labour intensive industrialisation path as a way to tackle the country's declining manufacturing sector, high levels of unskilled labour and an unemployment rate of 40 per cent.² 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, 25 per of which is for local content. Despite the potentially progressive nature of these economic development criteria, a number of concerns have been raised over their long-term effectiveness, including the extent to which they may help to generate long-term employment and a local manufacturing industry and the increasing ownership of the renewable energy industry by large international companies (Baker, 2015) as the following sections discuss in more depth.

Local content is defined as a percentage of project expenditure spent in South Africa, specifically, 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). Consequently, its accurate measurement has been

² This figure includes formal definitions of 25 per cent unemployment in addition to 'discouraged work seekers' who have given up finding work.

Table 1
Local content targets as a percentage of overall spend, RE IPPPP, Rounds 1–3.

Technology	Round 1		Round 2		Round 3	
	Threshold	Target	Threshold	Target	Threshold	Target
Wind	25%	45%	25%	60%	40%	65%
Solar PV	35%	50%	35%	60%	45%	65%

Source: Adapted from DTI (2013b)

problematic mainly 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.

As Table 1 depicts, thresholds and targets for local content have increased between each bidding round. While under rounds one and two it was possible to meet the local content requirements through ‘balance of plant’³, 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.

As a result of the increase in thresholds and targets for local content, a number of manufacturing and assembly plants have been set up for low technology components as we discuss below. 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 we explore, loopholes in these regulations have resulted in a number of solar PV developers side-stepping them 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 & Westin, 2013; Mulcahy, 2012). 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 ‘technological capabilities’. The consideration of further measures are now discussed in section 4.

National systems for technological capabilities

An upper middle income economy in terms of GNI per capita, South Africa faces significant challenges to its national system of innovation, including high levels of inequality, unemployment, and unskilled labour and poor levels of education. By the Department of Science and Technology’s (DST) own admission, the concept of a national system of innovation has limited traction, both in the extent to which it is “understood as something wider than the sum of traditional research and development (R&D) activities, and in the extent to which it had been fully absorbed into the strategies of key actors (including government departments and higher education institutions)” (DST, 2012). Significantly, the country does not have a well-established industry for the manufacture of renewable energy equipment (Ahlfeldt, 2013: xiv; Walwyn & Brent, 2015), or indeed manufacturing more generally (Bhorat et al., 2014).

Despite this, the country has established a number of national commitments in order to enable it to establish technological

capabilities for renewable electricity beyond thresholds for local content. Such commitments are included in a number of national plans and documents on growth and industrial policy put together by various different departments. They include the Green Economy Accord of the Department for Economic Development (EDD, 2011), the Industrial Policy Action Plan of the Department for Trade and Industry (DTI, 2013a) and the National Development Plan of the National Planning Commission (NPC 2013). However these plans are not necessarily consistent or coordinated (Musango, Brent, & Bassi, 2014). 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 in the Western Cape. Yet regardless how effective any national policy may be, an evident challenge for South Africa 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.

This facet is exacerbated by the fact that both wind and solar PV industries involve trajectories of increasingly complex technology and are more knowledge than labour intensive (Olsen, 2010:138), with greater requirements for semi to highly qualified skills and often internationally mobile labour. This relates to Lal’s (1993:102) statement that “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”. But a lack of relevant skills and expertise in South Africa was identified by a number of industry interviewees both at blue collar/artisan level (e.g welders and cutters in the case of wind) and white collar. Such a scenario raises questions over which parts of the value chain it makes sense to localise in the interests of competitiveness and the long-term maximisation of local employment (Eberhard, 2013). A related consideration is that of the spatial mobility and volatility of manufacturing, which as an industrial development zone employee described [in interview November 2014], “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.”

Studies for the potential of the localisation of wind (DTI, 2015) and solar PV technologies (Ahlfeldt 2013) have been carried out by various different departments and/or donors and private sector institutions. 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 a current Industrial Development Zone (IDZ) Act (DTI, 2014b). In order to be awarded SEZ status an IDZ must comply with various criteria and manufacturing facilities in an SEZ qualify for financial and other incentives including a reduced corporation tax rate. 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 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.

In parallel to the national policies that facilitated the emergence of a utility-scale renewable electricity sector following the introduction of RE IPPPP in 2011, a number of exogenous factors have played a role. More generally these factors include impacts of the

³ In the case of solar PV, all components of the plant other than the panels, and in the case of a wind farm, all infrastructural components other than the turbine and tower.

2008 global financial crisis on renewable electricity 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 electricity development and related investment started to shift to developing countries, including South Africa. This investment was accompanied by a manufacturing surplus, which saw European, US and Chinese companies in particular seeking other markets to absorb this. This surplus has contributed to fierce competition in South Africa as reflected in dramatic tariff drops⁴ between rounds one and four of RE IPPPP, particularly in the case of solar PV technology. Meanwhile as renewable electricity projects have become more profitable, banks and investors with a long-term history in conventional energy infrastructure have developed an emerging interest. The influence and requirements of finance as a key contributor to tensions between technological capabilities and GPNs is now discussed in further depth in section 5.

Technological capabilities and GPNs in tension

Essentially the South Africa case reveals a tension between national requirements seeking to enhance and augment technological capabilities, and pressures from GPNs. As we discuss here and in the following section, the implementation of local content requirements under RE IPPPP illustrates how the realisation of national priorities for employment generation, skills development and increased local manufacturing are at odds with the demands by financial institutions for project ‘bankability’.

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 and the company that carries out the engineering, procurement and construction (EPC) contract and operation and maintenance (O&M). The EPC phase usually lasts for a two-year term but with liabilities and equipment warranties generally lasting for five years after construction. On the project’s commercial operation date the O&M contract takes over with a tenure length that can vary between the full term of the power purchase agreement or a five-year rolling contract. Given that local content requirements are often considered an investment risk, banks tend to insist on internationally experienced contractors who have carried out a minimum number of analogous projects elsewhere in the world. That the technology in question be ‘proven’ is a fundamental consideration for the lender with regards to a project’s commercial viability (Yescombe, 2013), relating 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”. Consequently, contracts for the EPC, O&M and particularly the technology supply for RE IPPPP have to date been dominated by international companies (see Figs. 1 and 2).

As the EPC contract is generally the largest cost item in the budget at an estimated 60–75 per cent of total project cost (Yescombe, 2013:210), it is considered a major risk, for which reason South Africa’s lenders insisted that under rounds one to three the EPC provide a fully ‘wrapped guarantee’ or fixed-price turnkey contract around the whole project. While a fully wrapped EPC in turn increases project costs (Ahlfeldt, 2013:52), it gives lenders “the confidence and guarantees that the plant will perform the way you have agreed prior to awarding the contract” (bank

employee, November 2013). However, despite the EPC’s overall responsibility, much of the work will be carried out by national sub-contractors. However such an arrangement does not always run smoothly given that the foreign contractors in question tend not be familiar with the specifics of national requirements and so consider them a greater risk, which will in turn have cost implications.

There was a general sense that in rounds one and two of RE IPPPP 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 PV 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”.

A further constraint is the requirement that technologies be certified by the International Electrotechnical Commission. Consequently, small, medium and micro enterprises have been precluded from participating in national renewable energy value as technology and service providers (Rennkamp & Westin, 2013: 18). Moreover, 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, Hamann, & Fay, 2013: 4–9).

However some skills transfer from international to national firms may be evident in that according to some interviewees, large international electrical contractors such as ABB and Schneider are increasingly starting to subcontract to local companies. Furthermore, since round three there has been a shift from a ‘fully wrapped’ EPC to multi-contracting (Ahlfeldt, 2013: 53) which according to a bank employee (November 2013), “means going forward many of those sub-contractors can then act as the sole contractor”. While multi-contracting is more complex to manage in view of the number of different contractors involved it is also cheaper.

The specific dynamics of the EPC and O&M in relation to wind and solar PV are discussed in further depth in section 6.

Conflict within government

In addition to tensions between GPNs and local content requirements, other conflicts were identified in terms of ideological differences within government, most evidently between the National Treasury and the Department of Trade and Industry (DTI). Essentially, 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. However 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 holds the greater sway over how the economic criteria are

⁴ Since the start of RE IPPPP, the electricity tariffs paid to power producers submitted by bidding projects have dropped by 75 per cent for solar PV and 50 per cent for wind.

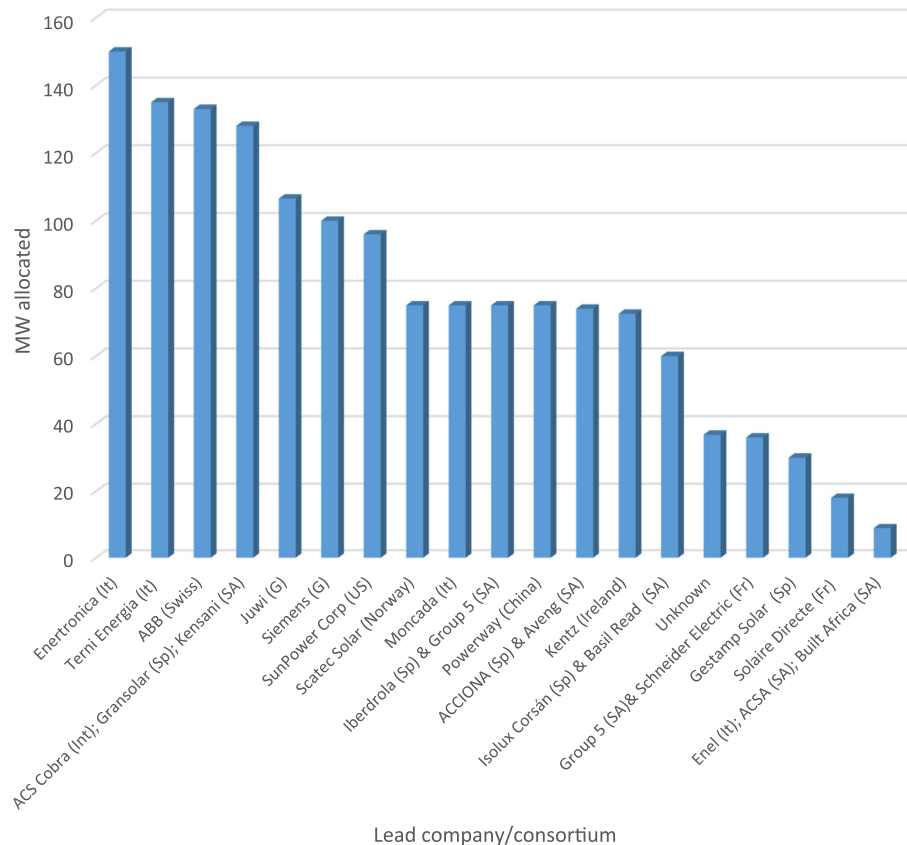


Fig. 1. Lead Engineering, Procurement and Construction firms for Solar Photovoltaic (PV) Energy, Rounds 1–3 of the Renewable Energy Independent Power Producers' Procurement Programme.

Source: Compiled by the authors. Note: Ch = China, Fr = France, It = Italy, G = Germany, Sp = Spain, SA = South Africa. Figures are based on publicly available information at the time of writing. The figures represent the lead EPC companies only and the authors note the national requirement that EPC companies must include a 40 per cent South African entity.

defined.

The lack of clarity over local content rules and definitions has also enabled international project developers, particularly of solar PV, to exploit and manipulate loop holes, as discussed in section 6. 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 "RE IPPPP requires high local content which quite honestly foreign investors have to manipulate to be able to achieve ... the process has got built in contradictions ... 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 appear to be due to a lack of understanding by policy makers of the nature of renewable energy technology supply chains and production processes, a finding not necessarily specific to South Africa (Schmidt & Huenteler, 2016: 9). As PV manufacturer (1) explained "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. 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), December 2014].

Trade tensions

A final issue is how South Africa's local content requirements align or conflict with international trade rules and agreements, an issue which currently lacks clarity (Kiragu, 2015). 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 (Curran, 2015; Lewis, 2014a,b). 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" given that international trade explicitly prohibits differential support to domestic over foreign technology.

Wind and solar PV

Having established the national and international context for such tensions we now examine their impact on the acquisition of technological capabilities in South Africa's emerging wind and solar PV sector.

Wind

The increasingly protectionist and competitive nature of the

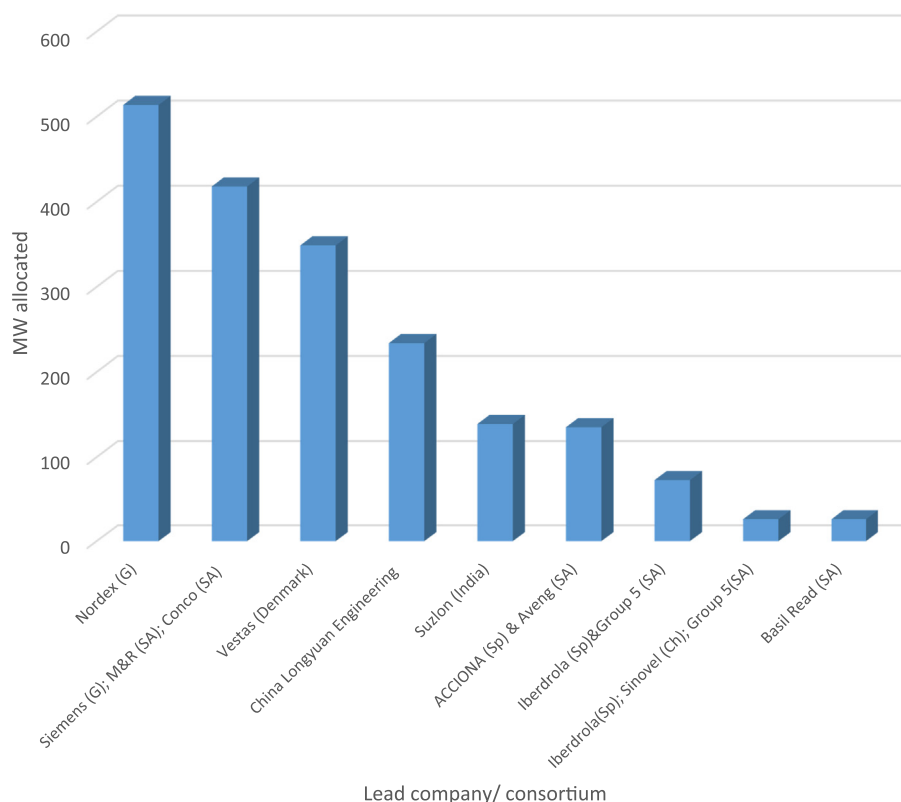


Fig. 2. Lead Engineering, Procurement and Construction firms for Wind Energy, Rounds 1–3 of the Renewable Energy Independent Power Producers' Procurement Programme. Source: Compiled by the authors. Note: Ch = China, Fr=France, It = Italy, G = Germany, Sp = Spain, SA= South Africa. Figures are based on publicly available information at the time of writing. The figures represent the lead EPC companies only and the authors note the national requirement that EPC companies must include a 40 per cent South African entity.

global wind industry (Lewis, 2014b: 515) with fewer and larger players that are constantly undergoing mergers and acquisitions⁵ has restricted the ability of South African companies to develop their own technological capabilities, particularly at commercial scale. South Africa's potential for localisation 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 (Lewis, 2014b: 1847). Reflecting the vertically integrated nature of the global wind technology supply chain, the EPC contractor is often the same company as the original equipment manufacturer (OEM), which supplies technology to the project and in many cases holds the contract for operation and maintenance. Such companies are able to offer multi-year service warranties and have the international reputation and years of experience required by debt financiers and equity investors (Lewis & Wiser, 2007: 1844). While European companies still dominate in the EPC and OEMs (see Fig. 1a), including Nordex, Siemens and Vestas, a significant minority of emerging market companies play a role, including India's Suzlon and China's Sinovel⁶ in round one of RE IPPPP, China's Guodian United Power in round three and China's Goldwind in round four. This reflects 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).

Localisation of wind power technologies can take a variety of forms (Lewis & Wiser, 2007) 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.

While the construction and maintenance of most components of a wind turbine such as blades, gearboxes and power converters (Lema et al., 2012: 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. And due to its size and weight the tower is the most expensive and logistically challenging component to import and transport. Under round one of RE IPPPP all wind towers were imported given that the local content requirement of 25 per cent could be met by carrying out the balance of plant locally. However following the increase in requirements under rounds two and three (see Table 1), having a locally manufactured wind tower was sufficient to meet local content requirements. This is because the tower takes up approximately 12–14 per cent of the project cost [turbine manufacturer in interview October 2014]. From round four and beyond all towers need to be manufactured in country.

Consequently two wind tower manufacturing plants have been set up in South Africa, one run by GRI industries, a subsidiary of Spanish Cooperación Gestamp, in the Atlantis IDZ in the Western Cape and the other by DCD wind towers in the Coega IDZ near Port Elizabeth in the Eastern Cape. 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

⁵ Recent examples include the sale of Acciona to Nordex (Lee, 2015) and the purchase of UK company, Blade Dynamics by GE (Weston, 2015).

⁶ 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.

manufacture towers for OEMs e.g Nordex and Vestas from where the equipment and the IPR is sourced. The arrangements between the OEMs and the manufacturers may not only restrict opportunities for innovation spill overs but also prevent the sourcing of services and supplies from other local companies. Firstly manufacturing is done under a non-disclosure agreement with the OEM whereby the local company undertakes only to manufacture and has no involvement in design. Secondly, because different OEMs have different designs, skills acquired from working on one tower will not necessarily be transferrable. Finally 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 to projects under RE IPPPP are currently imported. With the exception of the company Adventure Power, which makes small-scale blades, there are no utility-scale blade manufacturing facilities in South Africa and this is not currently anticipated. Far greater market certainty than currently exists would be needed for any blade manufacturer to set up in South Africa. OEMs such as Vestas and Nordex usually outsource blade manufacturing to specialised companies such as LM Blades, headquartered in Denmark. While 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”, the company's plans were shelved following the uncertainty created by the reduction of the wind allocation in the draft revised IRP in 2013, which has yet to be concluded (Baker et al., 2015).

An early attempt to set up a national wind manufacturing company in anticipation of RE IPPPP folded because it was unable to meet the requirements of project finance for ‘bankability’ and the two years’ operational experience. 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 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 2.5 MW wind turbines and rotor blades in South Africa for the growing local markets” (Rennkamp & Westin, 2013: 18) with an estimated 65 per cent local content. However the company folded in 2012. 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 [a South African company] wasn't able to do. They couldn't provide a parent company guarantee that would satisfy the banks.”

Solar PV

While wind is characterised as ‘design-intensive’, meaning that it requires “local knowledge networks of suppliers, manufacturers and users to capture the learning benefits”, solar PV is ‘manufacturing-intensive’, meaning that it requires less local learning and is more dependent on international networks of suppliers (Schmidt & Huenteler, 2016: 17). The nature of the solar PV supply chain is also more dispersed (Curran, 2015), incorporating many intermediate components such as panels, frames, inverters, transformers, tracking system, cable trays, cells and glass.

For this reason, contrary to the case of the wind industry, the company that carries out the EPC contract for solar PV is less often involved in the technology supply. There is also greater potential for innovation in solar PV than wind, given that the latter is more mature as a technology and therefore harder to break into (Rennkamp & Boyd, 2013: 12). That said, a number of solar PV manufacturers have 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 contractors carrying out the EPC are dominated by European and US companies (see Fig. 2) including Enel Green Power, Solar Reserve and Scatec Solar, 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. 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, the original market leader until 2008. Not only has this contributed to dramatic tariff reductions as witnessed in South Africa's case between rounds one and four of RE IPPPP, but has also been the source of significant international conflict, best illustrated by the anti-dumping legislation in the EU and US. 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: 1035).

The deep influence that GPNs have on the political economy of technological capabilities in South African renewable electricity is further illustrated by ownership patterns related to intellectual property and hardware associated with solar PV. 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,⁷ Yingli Solar, Trina Solar, Jinko solar, Build Your Own Dreams and Renesola (Power et al., 2016). While many of these companies are now integrated into international 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 & 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.

The nature of GPNs in solar PV, coupled with the inadequate enforcement and definition of local content rules has resulted in a number of solar PV developers being able to sidestep local content rules through ‘transfer pricing’. Under transfer pricing, a foreign component supplier in coordination with the project developer 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 above, local content is measured in financial spend. As renewable industry member (1) described [in interview November 2013]: “... companies like Enel⁸ 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

⁷ Once the world's largest solar PV equipment maker; following its collapse in 2013, Suntech was bought by Chinese company, Shunfeng Photovoltaic International.

⁸ 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.

Table 2
Manufacturing and assembly plants for solar PV in South Africa.

Company	Technology Type	Location	Maximum 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	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 per year	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 per year	JinkoSolar Holdings Co., Ltd	Unknown	2014	Jinko's first manufacturing plant outside China.
Sunpower	Solar PV panels	Cape Town	160 MW per year	Unknown	Unknown	2015	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)	Unknown	2015	
SMA solar	inverters	Cape Town	Unknown	SMA solar	Unknown	2014	

Source: Authors' own compilation based on interview data and publicly available information

approved under RE IPPPP (see Table 2), have had less than two per cent of their production capacity taken up by local orders. Such manipulation has led to module manufacturers either seeking 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 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. 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 four is a probable illustration of National Treasury's power over the bidding process for RE IPPPP and how local criteria gets defined.

The EU–China solar dispute, which "represents the most significant anti-dumping complaint the European Commission has ever investigated" (Lewis, 2014a: 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 (2014a,b) 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, 2014a,b).

Conclusion

This paper forms an early contribution to the emerging theme of

renewable energy technology capabilities in South Africa. It demonstrates how technology development in these industries has been shaped by the interaction of territorially embedded factors with global dynamics. Such dynamics include: the geographically dispersed nature of global supply chains and production networks in renewable energy technologies; 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. It has further highlighted the adequacy or lack thereof of national local content policies and other frameworks in enabling the development of technological capabilities. The extent to which South Africa's 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 the country's emerging industry and an area for further research.

We have used the theoretical literature of technological capabilities and global production networks as a lens. In doing so, it has allowed us to develop an analysis that merges international trends such as trade, finance and technology costs with the complexities of a specific national context, including politics. This is significant given that many studies on technological development are too focussed on national policy and do not consider global dynamics. With this in mind, we offer five conclusions.

First, rather than viewing renewable energy technology policy as a set of rational processes or deliberative outcomes, it is in fact much more a series of 'complex bargaining processes' (Coe et al., 2004) between national and international institutions, in turn bound up within deeper social, political, economic and technological trajectories. While South Africa's RE IPPPP has been internationally celebrated for facilitating the very rapid take off of a utility-scale industry within an otherwise coal-fired, crisis-ridden, monopoly electricity sector, there are concerns over the extent to which the potentially progressive economic development criteria will be realised. Specifically, the extent to which this will result in a new industrial base and new areas of technological capability, or instead result in 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".

Second, and relating to the theme of competitive dynamics within GPNs (Coe & Yeung, 2015), we have examined how dominant international firms in renewable energy manufacturing and technology supply are attempting 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 poses 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, over the extent to which South African firms, as relative latecomers, will be able to develop their own comparative advantage in the face of such stiff global competition.

Third, this paper has added to two emerging themes in the GPN literature: finance (Coe et al., 2014) and technological development in renewable energy (Dunford et al., 2013), and the powerful determination that the former has over the latter. 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 such as I-WEC have been precluded from participating in RE IPPPP as technology suppliers and/or service providers.

Fourth, this study demonstrates the geographic differentiation of renewable energy technology manufacturing and the technology dependent nature of deployment. In other words, it is a mistake to treat renewable electricity systems as "equal" in their type and scope; the political economy of South African wind technology differs markedly from that of solar PV. As discussed in section 6, solar PV offers greater potential for innovation than wind, given that the latter is more mature as a technology. However in the case of solar PV, technological components are being exported to Europe in an example of toll manufacturing, and in other cases 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. Technology supply and the EPC for the wind industry meanwhile is dominated by increasingly large and consolidated multinational companies, while smaller nationally owned companies have struggled or failed to gain entry to the market.

Fifth, and perhaps most significantly, the paper's findings reflect the 'deepening international divisions of labour' (Curran, 2015) and the subsequent vulnerability of labour as 'spatially trapped' (Coe et al., 2004: 472) when compared to the international mobility of production. 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. Despite their low-carbon credentials solar PV and wind remain at the mercy of global capital markets and many of the pitfalls of a globalised, networked economy. In some ways, such energy systems can achieve their environmental benefits only by perpetuating broader, inequitable trends at a much larger scale.

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Annex 1. Interviews conducted for this paper (2013–2015)

Type	Number of interviews
Project developers	5
Project community liaison officers	2
RET manufacturers/assembly plants	7
Industry/engineering general	5
Lawyers	2
Civil society	4
Unions	2
Bi-lateral donors	3
Debt finance and equity investors	3
National government departments	6
Municipal/local government	3
IDZ representatives	3

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