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The dynamics of renewable energy transition in developing countries: The case of South Africa and India

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The Dynamics of Renewable Energy Transition in Developing Countries
The Case of South Africa and India

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Abstract

The innovation dynamics in the transition to renewable energy industries in India and South Africa is explored, by examining the development of the two main renewable energy technologies and comparing the transitional approaches. The functions of a technological systems approach is used to trace the evolution of actors, networks and institutions that have had a bearing on the generation and diffusion of renewable energy technologies in these countries. Through this analysis we improve our understanding of the processes or functions involved in the formation and uptake of renewable energy systems in developing countries and identify the associated key challenges for policy makers managing the transformation process. Current technological and innovation systems approach analysing the evolution of renewable energy systems ignores renewable energy industrial evolution in developing countries. We argue that developing countries have different learning stages of industrial development and different learning strategies, which need to be considered when evaluating renewable energy innovation systems, which has remained neglected in existing studies. Functions that induce the transition are found to be weak in South Africa as compared to India. India compares fairly well in terms of development of positive externalities, degree of legitimation and entrepreneurial activities. However, the availability and effect of the inducement instruments in each country varies from one renewable energy technology to another. Wind and solar energy technologies are explored and their transitions compared.

KEYWORDS: renewable energy, technological innovation systems, low-carbon transitions

JEL Classification: Q42, Q01, O33

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1. INTRODUCTION

Brazil, South Africa, India and China countries are amongst the fastest growing economies in the world, with tremendous economic growth potential and similar among the BASIC countries. A trend is observed towards globalization as well as the commonality of desire and choice among emerging economies to grow economically and free themselves from previous prolonged and deep poverty traps. Economic growth is known to have the strongest influence on emissions levels, usually putting upward pressure on emissions. Presently the four BASIC countries mentioned above are facing similar challenges in restructuring the economy, maintaining a healthy and sustainable growth and in achieving an inclusive, equitable and green development. This means being equally involved in mitigating climate change and GHG emissions as the rest of the developed world. These challenges are resonant of the questions which existing scholars of innovation studies and sustainability are grappling with - understanding if the tremendous pressures of economic growth and development can lead to low carbon growth trajectories in developing countries. The transition to renewable energy technologies in India and South Africa[i] which forms two of the four BASIC bloc countries will be analysed.

Global warming and other impending environmental issues call for a new technological paradigm (Altenburg et al., 2010). It is well acknowledged among the wider international community on climate change that addressing the impacts of climate change and reducing future climate risks will require new technological solutions (Morey et al., 2011). Such paradigmatic shift is, according to Kuhn (1962), a change in the basic assumptions, or paradigms, within the ruling theory of science. This has been elaborated by Dosi (1982) to “technological paradigm” to mean a 'pattern' for solution of selected techno-economic problems based on highly selected principles derived from the natural sciences. It is primarily grounded on problem-solving activities such as ‘how to do things’ and how to improve them. For example, it implies shaping materials to adapt wind blades to specific wind conditions simultaneously improving technological performance.

Once a technological paradigm has been selected it shows a momentum of its own and develops along a defined “technological trajectory”. As renewable energy technologies are not entirely based on old industrial assumptions of production and consumption, they thereby require large-scale systemic and technological paradigmatic changes for transitions to occur. For example, solar energy technology has developed on the technological paradigm of solar space technologies, but its manufacturing has evolved on integrated circuit (IC) manufacturing of the information technology industry that uses silicon wafers in production. Moreover it will require replacing large and established energy systems and industries based on fossil-fuels.

Technological systems transitions involving technical change also tend to be path dependent contoured and channelled by technological paradigms, as the high costs of switching to new technologies discourage economic agents to abandon existing and established technological path. In evolutionary economics, David (1985) and Arthur (1988) have shown that path dependence plays an important role in the choice between two competing technologies – if one of the technologies has gained a lead somehow, it benefits from increasing returns[ii] to adoption and creates a dominant path. So when a technological trajectory is very "powerful" such as the current fossil-fuel based energy systems, it will be difficult to switch from one trajectory to an alternative one (Dosi, 1982). Energy systems based on fossil-fuels are huge and powerful and systemically embedded in every activity of our lives. Even with continued growth rates over the next two decades, wind and solar may only begin to replace the stock of conventional energy technologies well after 2020 (Jacobsson and Bergek, 2004). Besides, the proponents of the established energy system often attempt to block the diffusion of renewable energy technologies by influencing institutional frameworks and policies.

In this paper, the dynamics of the transition to renewable energy technologies, wind and solar energy, is being explored in terms of ‘technological functions’ within a technological innovation systems (TIS) (Bergek *et al.*, 2008). Technological functions are factors that shape and direct the transition to renewable energy technologies and may include functions such as legitimation and entrepreneurial experimentation, among others. The framework used in this paper provides a detailed view of how the development and diffusion of renewable energy sources takes place and help identify system weaknesses.

Although the two countries are evolving with considerably different path towards renewable energy technologies, the paper will highlight the key technological functions that are important in any given context of an industrial transition and help identify system weaknesses and illustrates how transitions are (or not) taking place in these countries.

The paper is structured as follows - Section 1.1 following the Introduction will provide the general conditions of fossil fuel and renewable energy patterns and CO2 emissions of South Africa and India. Section 2 will explain the technological innovation systems (TIS) framework and the functions that will be used in this paper. Section 3 will explain the methodology that will be used for the analysis and data collection methods and Section 4 will provide the results of the data and analysis. Section 5 will highlight the broad policy implications of the study as a conclusion of the paper.

1.1 INDIA AND SOUTH AFRICA – THE BASIC BLOC

India and South Africa are both heavily dependent on coal and are very large coal-producing economies, which will increasingly shape the global energy landscape. South Africa produced 255 Mt of coal and India 538 Mt in 2010 (World Coal Association, 2012). The IEA (International Energy Agency) estimates that 44 % of CO2 emissions in 2010 came from coal, 36 % from oil and 20 % from natural gas. South Africa accounts for around 1.2 % of global GHG emissions and 18% of emissions in sub-Saharan Africa, ranking 19th in the world (World Resources Institute, 2010). At an average of 9.2 tonnes CO2 per capita in 2005, the per capita emission rate was above the global average of 6.8 tonnes /year and almost three times as high as the sub-Saharan average of 3.2 tonnes (Carbon Planet). It almost equalled the average per capita emissions of 10.9 tonnes in the European Union and was higher than in the cases of China and India. Around 90 % of South Africa's power comes from coal and just 6 % from nuclear fuel.

India accounts for 5.6% of global GHG emissions, more than double that of South Africa, ranking 5th in the world in terms of total emissions. However, the per capita emission rate in India is much lower than South Africa at 1.18 tonne per person/year (Carbon Planet). A UNIDO study reported that although SA's industrial energy intensity[iii] fell, it remained more than double the world average (UNIDO, 2012). Energy intensity as shown in Table 1 below and is measured in unit tonnes of oil equivalent (toe) per million $ (constant year 2000 international million dollars).

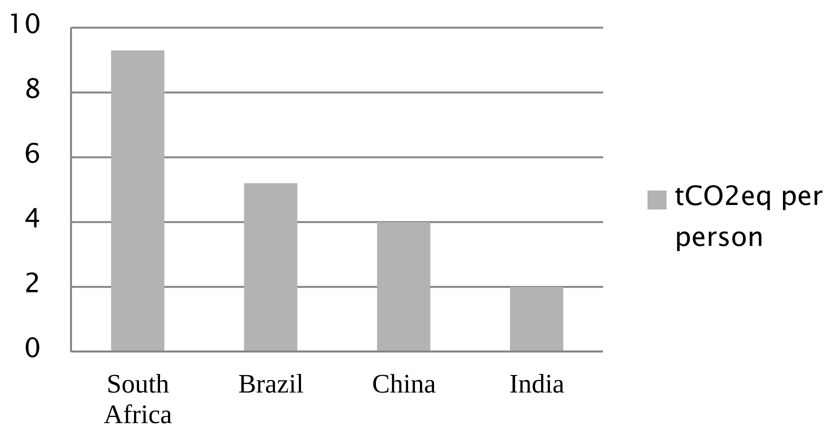
Table 1: The energy intensities of the BASIC countries, showing that South Africa is ranked the highest with 265.1 (tonnes of oil equivalent per 1 million $)

BASIC countries	Energy Intensity (toe/1M $)
Brazil	146.1
China	231.3
India	189.5
South Africa	265.1

Source: World Resource Institute, 2011

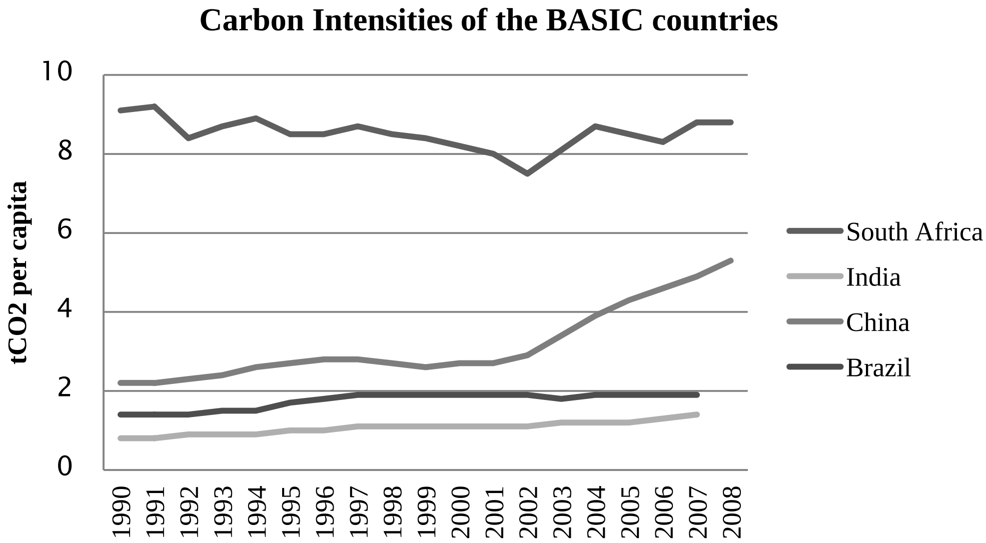
Coal presently constitutes a little over 50 per cent of India's total energy mix. Compared to South Africa, coal has been the chief energy source for India because it is found in abundance and is cheaper to exploit than some of the other energy resources. It would be difficult to reduce India's coal consumption, not just because of issues pertaining to path dependence, but because any significant reduction in coal consumption (even in the presence of a viable option) will have severe economic and political repercussions (Hosur, 2010).

CO2 Emissions per Capita of the BASIC countries



Graph 1: South Africa's CO_2 emissions per capita are high relative to the BRICS region and the rest of world, particularly in terms of carbon intensity of GDP. Source: Long Term Mitigation Scenario (LTMS), South Africa, 2009

So the transition to low-carbon technologies such as renewable energy technologies in India and South Africa will be slow and challenging, coupled with path dependencies and carbon lock-ins. A paradigmatic shift will be needed to avoid India and South Africa's fundamental requirement for coal and power generation based on fossil fuels in the future. These countries must deliberately harness paradigmatic shifts to develop early mover advantages and accelerate the transition.



Graph 2: The carbon intensity is high in South Africa relative to the BASIC countries and is measured in terms of metric tonne CO2 emissions per capita. Source: IEA, 2011

We analyse the wind and solar energy industries, and in terms of resource potential, both South Africa and India are comparable as they have immense resource potential in solar and wind energy. India shows large areas with annual average wind power densities of more than 200 Watts/m2 at 50 meter above ground level (MAGL) (CWET, 2010). A study by Mainstream's Energy Analysis Group confirms that South Africa has potential to generate over 70,000 MW of wind energy in total (2011).

The Pew Charitable Trust (2010) did not profile South Africa as there was insufficient reliable data on installed capacity within the country and nor does the UNDP New Energy Finance study (2012) profile countries with lower than 0.3

billion in total investments as in the case of South Africa. In 2010, India had 13065 MW of installed capacity of wind energy while South Africa is estimated to have a capacity of 8 MW (Darling wind farm), and whether this capacity is connected to the grid is unknown. In 2010, the total renewable energy capacity in India was 16 GW making it the 5th largest in the world (Pew Centre, 2010).

2. TECHNOLOGICAL INNOVATION SYSTEMS AND FUNCTIONS

We use a technological system of innovation approach to analyse the processes involved in the transition in India and South Africa, to a new technological systems in the energy sector. A technological system is defined as a '. . . network(s) of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of generating, diffusing, and utilizing technology (Carlsson and Stankiewicz, 1991).

The technological innovation systems are a variant of the generic innovation systems approach[iv]. Many of the major themes of innovation systems research were touched on by earlier scholars and their study has expanded rapidly over the past twenty-five years (Kastelle *et al.*, 2009). The first view placed emphasis on institutions (government, universities, research institutes and firms) which provide both opportunities and constraints within national innovation systems (NIS) (Nelson, 1993). While subsequent literature has shown that in some cases, institutions are more consistent within sectors than they are within nations (Breschi and Malerba 1997; Malerba 2005). Thus, the literature on innovation systems discusses national innovation systems (NIS) (Lundvall, 1992), regional innovation systems (Cooke *et al.*, 1997), sectoral innovation systems (Breschi and Malerba, 1997) and technological innovation systems (TIS) (Carlsson and Stankiewicz, 1991).

However, innovation systems approach treats technology as an exogenous variable, thereby neglecting the importance of technology as an independent variable of innovation (Carlsson and Stankiewicz, 1991). The argument in favour of TIS as an analytical approach is further supported by a strong representation of entrepreneurial activity and knowledge diffusion (Suurs, 2009). The functions of TIS and the inducement and blocking mechanisms, as will be discussed below, are relevant as the central role in understanding renewable energy systems is given to start-ups, small and medium-sized firms, and a strong focus on knowledge and technological diffusion processes are key.

Bergek *et al.* (2008) argue that the existing literature discussing innovation system failure tends to focus on perceived weaknesses in the structural composition of a system. It is considerably difficult to evaluate the “goodness” or “badness” of a system or a particular structural element or combination of elements without referring to their effect(s) on the innovation process. Therefore it will be important for any analysis to not only know if a particular actor is important for an innovation process but to complement the analysis in understanding the nature and sometimes degree of the actor’s influence. The TIS is thus developed and mainly to help us identify the central policy issues in a specific innovation system, and which according to Bergek *et al.* (2008) requires supplementing a structural innovation system focus with the process focus.

Moreover, there is a pressing need to develop new analytical frameworks when analysing renewable energy industries in developing countries. Though current technological and innovation systems approaches give us a new analytical framework for a low-carbon transitional analysis, they however ignore renewable energy industrial evolution within the dynamics of developing countries. Developing countries have different learning stages of industrial development, and different innovation capabilities and learning strategies that need to be considered when evaluating renewable energy innovation systems. Renewable energy technologies like wind and solar that are being diffused in developing countries have mostly been transferred, adapted, modified and/or acquired from firms in advanced countries.

However, the diffusion of technologies in developing countries can be impeded by a capability failure such as a shortfall in the technical skills needed to adopt a new technique, organizational inadequacies which prevent exploitation of a new techniques, or deficiencies in business skills and understanding on the part of the firm or the infrastructure on which it depends (e.g. banks), which prevents the firm from taking rational decisions (Arnold and Guy, 1991). Bell and Pavitt (1993) and Bell (2010) define innovation capability[v] as one which creates new configurations of product and process technology, and implements changes and improvements to technologies already in use. In the case of low-carbon innovation, such capability requires a strong base of localized innovation activity to complement solar and wind energy technologies imports.

Many developing countries possess innovation capabilities that are weak or fragmented, and the systems of interconnection between the actors of an innovation system are often underdeveloped to enable capability building and effective learning strategies (Gallagher *et al.,* 2011). Technology strategies are based on an understanding of what impedes the realization of the potential gains that improved technologies have to offer (Sagar. 2009) and they contribute to the building and strengthening of innovation capabilities (Bell and Pavitt, 1993). Further, low-carbon innovations and technology strategies in emerging economies demand the building of local capabilities in order to adapt, develop and diffuse them. Therefore, low carbon capabilities need to be built in ways that are sensitive to the local context, exploiting local advantages such as existing research capacity, skills and local availability of natural resources (Perrot and Filippov, 2011; Climate Strategies, 2012). In other words, it demands a certain level of absorptive capacity[vi] on the part of local firms, and skills and mobility of local employees, in addition to openness to trade and policies to induce foreign investors to bring appropriate technology to developing countries (OECD, 2009).

Sagar (2009) identifies two types of technologies - transferable technologies/products, which do not need to be significantly modified or redesigned such as solar and wind energy systems. But the manufacturing of which requires the availability of local capabilities (Perrot and Filippov, 2011). The other are technologies/products requiring significant modification and adaptation, like electrical equipment such as air-conditioners or refrigerators, are where the compressor and other components may need some changes in order to perform suitably in local conditions or crops which need to be modified for local soil and rainfall patterns. In both types of low-carbon technologies, local technological capabilities play an important role in the adaptation and modification process (Sagar, 2009) and which Bell and Pavitt (1994) collectively call technological capability.

3. METHODOLOGY

A process approach or sequence analysis has been used in this approached as suggested by Bergek et al. (2006). This approach conceptualizes development and change processes as sequences of events and takes the order of all relevant processes into account. The basis of the analysis is the event and is based on functions as illustrated in Table 2. For the analysis of this paper we have used these events to map changes and developments that have been taking place in the two countries. Data were collected by following events that are reported at the system level, for e.g. newspaper archives, industry reports and professional journals. These events can be workshops on the technology, the start-up of R&D projects, and even expression of expectations about the technology in the press.

Table 2: The seven functions of a Technological Innovation System (TIS)

SEVEN FUNCTIONS	EXAMPLES OF INDICATORS
1. Knowledge Development and diffusion	R&D Projects
	Bibliometric: Patents and publications
	Investment in R&D
	Technological capabilities
	Number of workshops and conferences
	Size and intensity of learning networks
2. Influence on the direction of search	Taxes and prices in the energy sector
	Regulatory pressures (e.g. quota systems)
	Govt./industry targets regarding use of specific technology
	Estimates of future growth potential
	Articulation of interest by leading customers
3. Entrepreneurial experimentation	Number of new entrants
	Number of diversification activities of incumbent actors
	Number of experiments with the new technology
	Degree of variety in experiments
4. Market Formation	Number, size and type of markets (installed capacity)
	Timing of market formation
	Drivers of market formation (e.g. support scheme)
5. Resource Mobilization	Volume of capital and venture capital
	Volume and quality of human resources
6. Legitimation	Attitude towards technology among stakeholders
	Rise and growth of interest groups
	Extent of lobbying activities
	Political debate in parliament and media
7. Positive Externalities	Strength of political power of TIS actors
	Activities aiming at uncertainty resolution
	Existence of clear division of labour/development of specialized intermediaries/development of pooled labour market
	Information and knowledge flows

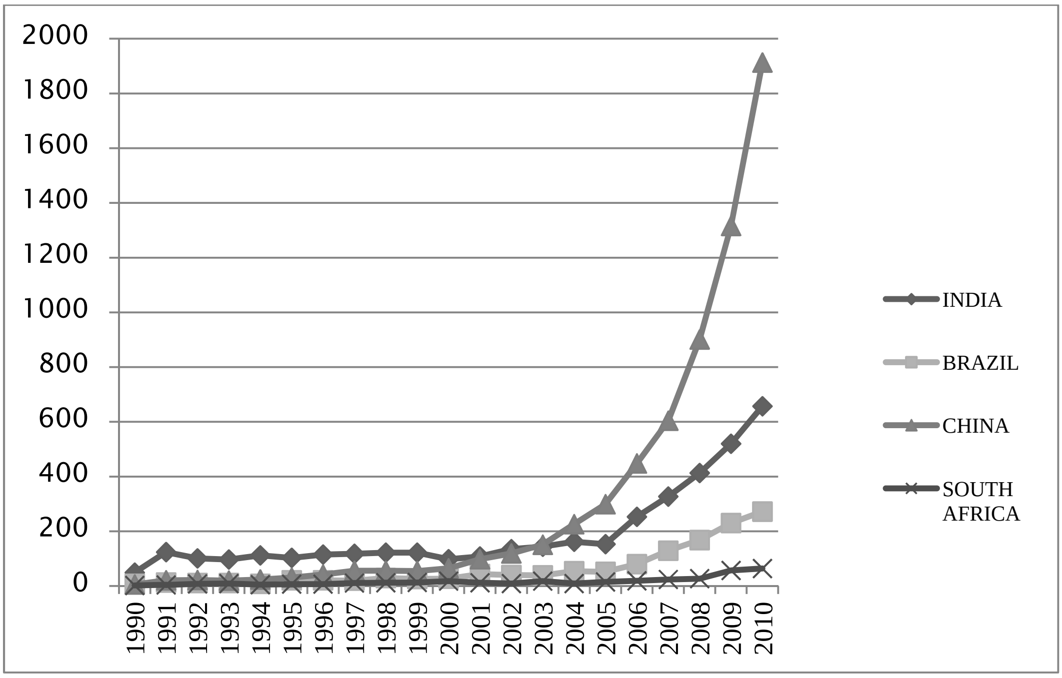
Source: Adapted to include innovation index and capabilities from Bergek et al. (2010)

The methodology is a six-step process and involves - (i) Identifying the technology/technology field or a product (wind turbines or solar PV panels) (ii) identifying the actors and networks using bibliometric data/patent data/ snow-balling effect (talk to actors in the industry who refer to another actor) (iii) At this stage we move from structure to functions which means describing what is actually going on in the system in terms of 7 key functions, and what is achieved in the system by these functions (iv) assessing how well the functions have fulfilled their goals. Goals have been set in terms of desired functional patterns, for example, if a target installation of 1800 MW of wind by 2012 has been achieved by South Africa (v) identify the mechanisms that induce or block development towards the desired functional pattern (for e.g. the process of legitimation is weak in SA and maybe blocking the desired goal of achieving their 1800 MW RE target by 2012 (vi) ad finally, to specify the policy issues related to these inducement and blocking mechanisms

4. RESULTS AND DATA ANALYSIS

Knowledge Development and Diffusion

In 2004, a South African National Energy Research Institute (SANERI) now SANEDI, was started to focus on indigenous research and development of energy technologies and its demonstration, including renewable energy. It created and funds specific research and learning networks by collaborating with the University of Johannesburg on the R&D of thin film solar PV and the Nelson Mandela Metro University on solar PV projects. It is funding a project on ruthenium dyes for dye sensitized solar cell with Fort Hare University. The total R&D funds that were allocated by SANERI amounted to 29.4 m ZAR totalling 31 research projects in 2007/2008. There is no research and funding data available for later years. SANEDI focuses on several other energy technologies such as carbon capture and storage and coal-to-liquids, a breakdown of each project cost per technology was not available. Presently, SANEDI is mapping the Wind Energy Atlas with technical assistance and funds from RisØ Labs of Denmark (SANEDI).



Graph 3: The number of publications of the basic countries

Bibliometric data Source: Web of Science, 2011

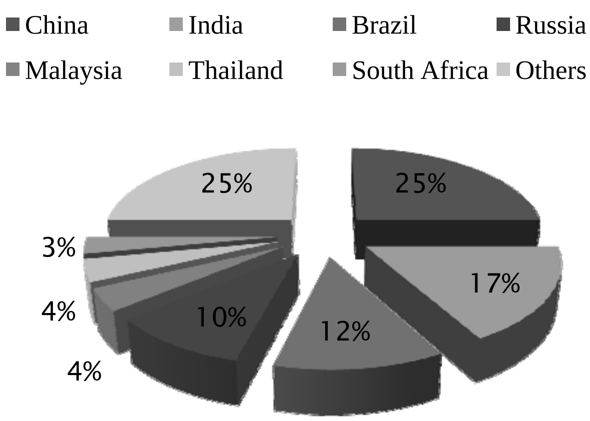
Graph 3 above represents the statistics on scientific and engineering publications in renewable energy an indicator of the knowledge base/ or technological capabilities function of a TIS. Evidently South Africa lags behind not only India but the other two BASIC countries – China and Brazil. Being an output indicator it reflects the intensity of scientific and R&D activities in renewable energy. One observes that research activities in renewable energy were more or less at the same level until early 2000 for the BASIC countries when these technologies started receiving increasing attention in the industry, research and academia. India exceeds South Africa in terms of per research output in renewable energy technologies.

In India, the learning networks are more in number and broader in research scope than in South Africa in the field of wind and solar energy technologies. The National Aerospace Laboratories (NAL) of India has been involved in the research and development of wind turbines since the 1980s and adapted the technologies to the conditions of India as its wind speeds are lower than the average European wind speeds (Kristinsson and Rao, 2006) These learning networks are often instrumental in driving new knowledge and diffusing renewable energy technologies. Two

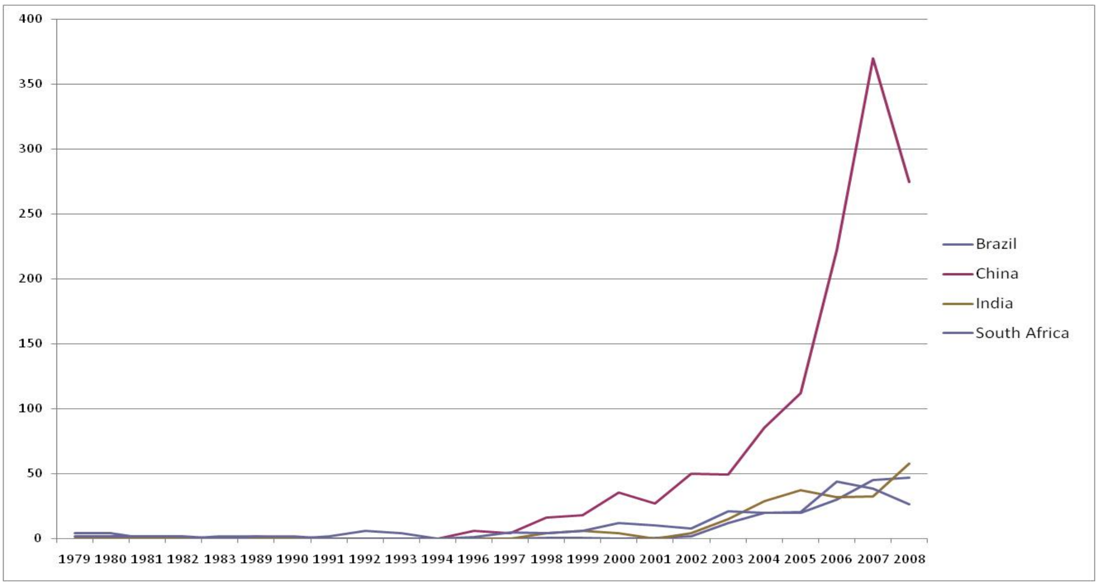
Environmental Training Centres in 1994 and the Centre for Wind Energy Technology (C-WET) in 1998 were set up by MNRES as autonomous training and R&D institutions respectively. RisØ Labs, a similar testing and certification centre to C-WET, has been instrumental in driving the technological development of the Danish wind energy industry since the 1970s (Douthwaite, 2002). The two Indian training centres were developed in co-operation with Denmark to provided training to regulatory authorities, municipalities and companies in India.

South Africa is the 7th largest recipient of technology indicated by patent flows in solar PV and thermal technologies and India is way down below (OECD, 2009). However, India is among the four countries in the world in which solar PV patents exceeds solar thermal, not including South Africa. Patent flows and activities indicate the extent of knowledge development and diffusion processes in a country. Graph 4 shows the level of licensing and IP-based activities in wind and solar, among other low carbon technologies, showing that India ad

Graph 4: Licensing and IP-based commericalization activities involving Clean Energy Technologies (CETs)



Source: OECD, 2009



Graph 4: Patents are one of the other indicators of knowledge development and diffusion in renewable energy technologies in the BASIC countries. India and South Africa are comparable and at par when it comes to patenting technologies. This is an indicator also representing the direction of search and knowledge diffusion, two interdependent TIS functions. Source: USPTO and EPO

Influence in the Direction of Search

Influence in the direction of search by the South African government has been positive as the country has increased its target ceiling on renewable energy potential from 1200 to 1800 MW by 2012. A very popular policy mechanism, feed in tariffs[vii] or REFIT, that has been historically pivotal in driving growth in European countries and in India, was scrapped for competitive price bids in mid-2011 and may likely dampen the industry take-off stage. This has elevated price uncertainties and investment risks associated with market formation.

There are various industry targets and future growth potentials that have been put forward by the government of South Africa, namely the White Paper on Renewable Energy Policy (2003) and Long Term Mitigation Scenarios (2008) showing some evidence in its influence on the direction of search. Commitment by the government to renewable energy developed was shown in the Industrial Policy Action Plan (IPAP2) in 2010 but which showed that REFIT was linked to its development. By August 2011 the government scrapped REFIT and introduced competitive pricing making the renewable energy landscape investment riskier although it capped the upper tariff bid rate. The White Paper of 2003 had unrealistically set targets of reaching renewable energy installations at 10 000 GW by 2013. A subsequent

Integrated Resource Plan (IRP) for electricity released in 2010 targets wind to achieve 800 MW (2010-2013), CSP 200 MW (2014-2015) and solar PV 2400 MW (2012 – 2019). Although targets to achieve 10 000 MW of wind capacity by 2020 shows the government's intention regarding the use of a specific technology, issues around how to achieve the targets have been ambiguous in South Africa (Bekker *et al.*, 2008).

India has set a target to achieve 15% RE electricity injection into the grid by 2020. As shown in Graph 5, India targets to achieve 40,000 MW (or 40GW) of wind and 8000 (8GW) of solar by 2022. Some states are approaching this target, but some states are lagging behind.

Graph 5: Indian Clean Energy Target by 2022. Source: Ministry of New and Renewable Energy, India

India is expected to exceed the target of adding 12.4GW of grid-connected renewable energy by the end of 2012 (BNEF, 2012). India has been aggressively promoting solar power projects since 2010 as part the National Action Plan on Climate Change. Grid-connected solar also saw a substantial increase, up from 18MW in 2010 to an estimated 277MW by the end of 2011 (BNEF, 2012). The Jawaharlal Nehru National Solar Mission (JNNSM) plans to install 22,000 MW of solar energy by 2022 by using a mix of feed-in-tariffs and Renewable Purchase Obligations (RPOs). Within just three years, 2009-12, India has gone from almost zero to close to 1,000 MW of solar installations in the country (CSE, 2012).

In 2011, India announced that PV project developers participating in the first 150MW phase of its Solar Mission would only be eligible for support if they used locally assembled modules (BNEF, 2012). For the main 296 MW phase which will be allocated by March 2012, both cells and modules have to be produced locally.

Such local content[viii] rules create positive externalities in an industry and influences the direction of search. Other than jobs, local content has the ability to build a country's local manufacturing and knowledge and skills base, and thus encourage localization of manufacturing (Lewis and Wiser, 2007). Though India's solar mission project mandates a local content requirement, it does it only for the crystalline PV technology and not for the thin-film PV technology. This has dampened the solar industry in 2012, forcing closure and debt restructuring with no new demand (CSE, 2012). Approx. 60% panels installed in India are thin-film while only 14 per cent of global capacity is thin-film.

South Africa has a local content requirement (increased 45% for wind energy in the 2nd bidding phase) and those of other countries are shown in Table 3. South Africa local content requirements are sensible, but there is a glut in global supply of solar modules and cells, which the country had to bear in mind when making decisions about establishing manufacturing capacity locally (Donnelly, 2012).

Table 3: Comparison of local-content requirement in the BASIC countries

Country	**Period**	**Local-content requirement**
China	1996-2008	Wind turbines under China's NDRC were required to source at least 70 percent of content from local manufacturers
Brazil	2005-2009	Brazil had 60% compulsory under their PROINFA wind energy program, and from 2009 went under the auctioning system. 60% local content is mandatory for those who want financial assistance. There is no solar program yet.
India	2003 - 2012	Customs and excise duties favour local assembly and manufacturing for both wind and solar Capital subsidies for Solar Mission project; and other solar projects but applies only for crystalline solar and not thin-film
South Africa	2011-2012	Was 35% in the previous year and is at least 45% percent local content for wind and development (in 2nd round bidding) in 2012

Source: Energy Research Institute (ERC), South Africa (2012), SANERI, South Africa (2012) and other sources

Entrepreneurial Experimentation

India fairs comparatively well in entrepreneurial experimentation in both the solar and wind energy industries. Entrepreneurial activities were recorded after India embarked on a massive economic reform program in 1991 encouraging private-sector participation in many sectors of its economy. During this period the Government of India (GOI) shifted its focus of wind energy policy for stronger private-sector involvement, extending public finance to private-sector wind-power projects and providing fiscal and financial incentives to encourage private investments (Mizuno, 2006).

Local companies like RRB Energy were engaged in wind energy development (large-scale) activities as early as 1989 by absorbing skills that were transferred from the wind energy developed cooperation between the government of India and Demark in 1986. In 1994 Suzlon was founded in a move to secure an existing textile company's energy needs but which soon emerged as one of the world’s largest wind turbine generators (WTG) manufacturers, with 7% of the world market share by 2010. Between the years 2004 to 2007, Suzlon bought two European companies that help expand its technological capability in gearbox manufacturing and gave access to the growing European market.

From the mid-1990s and until 2010, India has seen the entry of approximately 16 private wind energy companies and most of which were created through various technological collaboration with foreign companies, constituting world-class Danish and German wind turbine manufacturers. There were diversifications of local companies like NEPC India (wind and now solar PV) from electrical power Equipment Company; Moser Baer (solar PV) from the laser compact disc manufacturing industry; and Tata BP Solar from steel manufacturing. Shriram diversified from the financial sector into energy engineering 2001 and entered into a technological joint venture with Italian company Leitner technologies in 2007 to jointly manufacture and install large scale wind energy generators.

In South Africa there is no evidence of entrepreneurial experimentation in the wind and solar energy industry. Although several foreign wind and solar farm projects are currently developing energy farms with an aim to develop 1800 MW wind farms and 600 MW of solar by 2012, entrepreneurism is currently low with no evidence of participation of local firms.

According to Pew Charitable Trust (2010) the 2012 target for renewable energy installed capacity is expected to be at 1667 MW for South Africa. It was zero by the end of 2011 other than the Eskom wind demonstration farms with installed capacities of 8 MW. Various government bodies like SANEDI and Eskom have acknowledged that there are internal management problems in running these projects and have power generation in these sites stopped.

Approximately 30 companies that bid were selected to develop solar and wind energy farms, and one hydro power, in South Africa, with a total capacity of 2934 MW allocated in contracts and not actual generating capacity. A total of 20 GW of renewable energy capacity is anticipated to be installed in the country by 2030 according to the Integrated Resource Plan, which outlines its aim to achieve renewable energy targets by 2030. Early in 2012, Tata Power of India entered into a joint venture agreement with Exxaro coal of South Africa to create a company called Cennergi, which will focus on the investigation of feasibility, development, ownership, operation, maintenance, acquisition and the management of electricity projects in SA, Botswana and Namibia. Other companies that are bidding as independent power producers (IIPs) for the bids in South Africa from other countries are, namely, Gaz de France (GDF) - Suez and Electrawinds of Belgium (both project developers) and Suzlon of India and Goldwind (wind turbine manufacturers), among 100 other companies from across the world.

Market Formation

Attributes of market formation is weak in South Africa as compared to India. The first commercial wind power development project, Darling wind farm, began generating power in 2008 with 1.3 MW capacity and is currently at 5.2 MW. And the national utility Eskom’s Klipheuwel wind farm started in 2003 today generates 3.16 MW of electricity. There is however no reliable evidence to ascertain if energy generated from these wind farms are connected to the electricity grid. There are no wind components manufacturing plants in South Africa though there are plans to set up few, claimed by wind manufacturing companies like Suzlon (India) and Goldwind (China). However, before which "markets will have to be first formed" in South Africa (Goldwind, 2011).

Imports of technology components such as wind turbines and solar products are treated as capital goods and are therefore 100% tax exempted in South Africa. In India, there are import tax exemptions that have been increased to 100% for some wind turbines components (GWEC, 2011). Accelerated tax depreciation of 50% of capital cost in year 1, 30% in year 2 and 20% in year 3 exists for all renewable energy projects in South Africa. In India, there is an accelerated tax depreciation of 80% along with feed in tariff rates for large scale wind and solar technologies (GWEC, 2011). A 100% FDI investment is now allowed in renewable energy generation projects in India, applicable since 2011.

	India	**South Africa**
Total RE Investment (2009)	US$ 2.3 billion	US$ 125 million
Total RE Investment (2011)	US $ 10.3 billion	
5-year growth rate	72%	NA
Installed Clean Energy (2009)		
Total RE capacity	16.5 GW	NA
Total power capacity	9%	NA
Growth rate	31%	NA
Total installed capacity (2010)		
Wind	12 GW	8 MW
Solar	15.2 MW (12.3 MW GC)	NA

Source: Compiled from G-20 Factbook, UNDP New Energy Finance (2011), Pew Charitable Trusts (2010) and Indian RE Status Report 2011, Ren21. Abbreviations: GW = Gigawatt and MW = Megawatt and GC = grid connected

In India, total financial investments in renewable energy grew and were up 25% to $ 3.8 billion in 2011, ranking 8th in the world. This growth has been attributed to a number of factors including a race to exploit accelerated depreciation tax break for wind projects before it is reformed in 2012; the government's Solar Mission to develop 1GW grid connectivity by 2013; and the launch of Renewable Energy Certificates and Renewable Purchase Obligation Schemes (New Energy Finance, 2012).

Table 1: Financial Investment in Renewable Energy in India by sector and asset class, 2010, $BN. South Africa does not profile as its current total investment is below $0.1bn

	Asset Finance	Public Markets	VC/PE	Grand Total
WIND	2.3	0.3		2.6
SOLAR	0.4	0.1	0.03	0.5

Source: Bloomberg New Energy Finance, 2012. South Africa has not been profiled in the report as it omits countries with less than $0.1bn in renewable energy investments by 2011

Resource Mobilization

According to the Global Competitiveness Report (2010-2011) in terms of quality of scientific research institutions India is ranked 25th and South Africa is ranked 42nd globally, while in terms of higher education and training India is ranked 38th and South Africa 42th. Quality and volume of human resources indicate the capacity to mobilize a country's resources and determines the innovative capability of a country (Bell and Pavitt, 1994). An additional factor that drives such resource mobilization and knowledge development and diffusion is the degree of innovation and sophistication levels in a country. India and South Africa ranks 39th and 44rd respectively and the indicator imply that firms in these countries design and develop cutting-edge products and processes to maintain their competitive advantage. There is sufficient R&D by the private sector making the environment conducive to innovative activities.

In terms of total private investment in renewable energy, South Africa has invested $ 125 million up to 2009 and of which 2.4% has been invested in wind energy projects, 53.5% in biofuels and 44.1% in other renewable (Pew Charitable Trust, 2010). In 2011, local utility Eskom received $365 million loan from the African Development Bank to help pay for a 100MW solar thermal plant in the Northern Cape and a 100MW wind farm in the Western Cape. India on the other hand invested $ 2.3 billion by the year 2009 and of which 59.5% has been invested in wind and 4.2 % in solar. India has mobilized its resources better than South Africa in terms of volume of private investments and volume and quality of human resources.

Legitimation

As far as articulation of interest and legitimation by stakeholders are concerned, Eskom, South Africa utility, is the sole purchaser and distributor of power generated from renewable energy and not municipalities (Davie, 2008). It currently supplies 95% of power but is recently unable to keep pace with growing energy demand. Although Independent Power Purchasers (IPPs) have been assigned to generate 30% of South Africa's total electricity output, Eskom can determine the price at which they can buy electricity from IPPs. In addition, there is no legal-framework around power buy-back between Eskom and the end customer and municipalities. Because the private sector is prevented from securing power purchase agreements that reflects their cost of investment in power plants, the market was not only uncompetitive (Bekker *et al*., 2008) and is far from being conducive for renewable energy development.

In 2010, the World Bank approved a $3.75 billion fund for a new 4800 MW coal-fired power station proposed by Eskom through its Clean Technology Fund, which clearly had provisions for other energy technologies like wind and solar. This indicates that the larger political debates involving various stakeholders are not engaged in discussions about climate change and there are no visible political attempts to make effective and planned transitions to low carbon technologies.

Sasol is a major oil and gas, and mining company dominating the energy industry and accounting for roughly 35% of South Africa's liquid fuel needs and producing over 4% of the country's GDP. Sasol is currently one of the biggest carbon emitters in the country, along with national energy utility Eskom, because of their dependence on power derived from the burning of coal. Clearly, the firm's technological paradigm is based on conventional thermal technologies - cutting-edge coal-to-liquids (CTL) and other fossils fuels-based technologies. Because of Sasol's sheer size, political prowess and enormous subsidies it receives in the country it will find it difficult to switch to other technologies of lower performance and new and expensive technologies.

In India there is visible political will to move to low-carbon technologies as made apparent by the creation of a national institution, the Ministry of New and Renewable Energy Technologies, in 1992. However, the processes involved in transiting to low-carbon technologies in India are often bureaucratic in nature and steeped in red-tapism preventing stakeholders from taking action. There is considerable resistance among state-run utilities to grant “third-party sale” facility to wind power producers (Kristinsson and Rao, 2006) as the 30-odd states of the country have their own independent power generation and distribution facilities owned and managed by state-run utilities. According to GWEC (2011), there is lack of an appropriate regulatory framework to facilitate purchase of renewable energy from outside the host states; there is inadequate grid connectivity in India (in South Africa grid connectivity is 95%); high wheeling cost; and bureaucratic delays in acquiring land and obtaining statutory clearances.

Development of positive externalities

The availability of funding options can be seen as a means to reduce market uncertainties and marks the development of positive externalities. The Indian Renewable Energy Agency (IREDA) has played a significant role in the promotion of renewable energy, attracting bilateral and multilateral financial assistance from world institutions and the private sector (Karlsson and Rao, 2006). In 1993-1994 the World Bank provided IREDA with financial assistance of $ 43 million for wind energy alone. Soon after, a dozen financial institutions entered the renewable energy market, local and international. However, there are a multitude of regulatory agencies in India that adds to the confusion and aims little at resolving uncertainty for stake-holders. For example, the Central Electricity and Regulatory Commission (CERC) and each of the states have their own set of guidelines for determining the feed-in-tariffs from renewable energy sources (GWEC, 2011).

In 2011, the International Development Corporation (IDC) of South Africa started financing large-scale renewable energy projects (over US $100,000) with a budget of US$3.7-billion investment over the next five years (Nkosi, 2011). Few renewable energy projects in wind are already under development through its financing mechanism, details of which are unknown.

The Government of India has been aggressively promoting solar power projects since 2010 as part the National Action Plan on Climate Change. The Jawaharlal Nehru National Solar Mission (JNNSM), plans to install 22,000 MW of solar energy by 2022 by using a mix of feed-in-tariffs and Renewable Purchase Obligations

(RPOs). Within three years, 2009-12, India has gone from almost zero to close to 1,000 MW of solar installations in the country (CSE, 2012).

5. CONCLUSION AND POLICY IMPLICATIONS

A 2012 report from Bloomberg New Energy Finance said that a sluggish economy did not hamper worldwide investments in renewable energy projects (solar power, wind energy and geothermal energy). Europe as a whole saw clean energy investment rise 3% to US$100.2bn in 2011, with the strongest features being solar installations – both large-scale and distributed – in Germany and Italy, and offshore wind farm financings in the North Sea. India led the table in terms of growth in investment with a jump of 52% to US$10.3bn, while Brazil clocked up a respectable 15% increase to US$8.2bn. The US$48 billion new investment in China merits attention in terms of scale and growth in renewable energy technologies and installations. Significant investment is also starting to be seen in Africa, such as Egypt and Kenya, which posted the highest percentage increase of all developing regions, if the emerging economies of Brazil, China and India are excluded. In Kenya, investment climbed from virtually zero in 2009 to $1.3 billion in 2010, across technologies such as wind, geothermal, small-scale hydro and biofuels.

South Africa, given its immense resources and renewable energy potential disproportionately lags behind major emerging economies such as India, Brasil and China. It also lags behind other African nations such as Egypt, Kenya and Zambia. However, it is expected that South Africa is likely to be one of the most important locations in the continent for renewable energy over the coming years. It is in the second round of its bidding stage for independent power producers to build up 20GW of renewable power capacity.

In terms of knowledge development and diffusion, although efforts are made in South Africa to promote renewable energy technologies, it lags behind other countries such as India and most of its efforts are recent, as early as 2004. Public funding spending has been put in new and unproven technologies such as Carbon Storage and Capture (CCS) because of path dependent tendencies – its heavy dependence on low-cost coal-based technologies in the past and in recent years. However, recent developments driven by a competitive bidding process will increase private investment flows into the country and direct the future transitions to renewable energy systems, principally solar and wind energy technologies. In contrast, the learning networks in India are more in number and broader in research scope than in South Africa, and particularly when compared to wind and solar energy technologies.

The benefits of positive externalities of the efforts and initiatives in the diffusion of solar and wind energy technologies have just started in South Africa and are therefore they are not evident yet. In India, despite some regulatory ills, a dozen financial local and international institutions entered the renewable energy market and have spear-headed the implementation and development of renewable energy projects.

As far as articulation of interest and legitimation by stakeholders are concerned, Eskom of South Africa is the sole purchaser and distributor of power generated from renewable energy and not municipalities. Late last year in 2011, South Africa utility Eskom received $365 million loan from the African Development Bank to help pay for a 100MW solar thermal plant in the Northern Cape and a 100MW wind farm in the Western Cape. The utility is a monopoly and greatly path-dependent on fossil-fuels that are hugely subsided, with little direct incentive in switching to renewable energy sources of power generation. Efforts made by Eskom are thus locked-in on a fossils fuels-based path. In contrast, there is visible political will to move to low-carbon technologies in India. There is lack of an appropriate regulatory framework to facilitate purchase of renewable energy from outside the host states. There is inadequate grid connectivity in India, in contrast to South Africa (which is at 95%).

South Africa has elevated price uncertainties and investment risks, and the absence of manufacturing base in both wind and solar power. The latter implies that innovation capabilities in South Africa are both weak and fragmented.

The transition to low-carbon technologies like wind and solar energy technologies in India and South Africa, are recorded at different stages of industry and technological development. However, for both countries the transition will be slow and challenging, coupled with path dependencies and carbon lock-ins. A paradigmatic shift will be needed to avoid India and South Africa’s fundamental requirement for coal and power generation that are currently based on fossil fuels. These countries must deliberately harness paradigmatic shifts to develop early mover advantages and accelerate the transition towards renewable energy technologies. It is evident that India is making efforts and developing ways to bypass the plight of many developed countries, which rely excessively on a fossil fuel-based energy infrastructure. However, India's embrace of sustainable development through a transition will take decades to realize because the size and scale of its transitional challenges are enormous. On a positive note, there is evidence that India can achieve both economic development and sustainability.

This paper has implications in policymaking as it allows policy makers to identify the processes and components and shows where intervention is likely to matter most in each of these transitions. Policy changes and/or energy transition specialists should specifically target at improving the functions or innovation processes of the technological innovation system. Rather than aiming to implement renewable energy technologies and kick-start an industry it would be more useful to understand which actors and processes can be put in place to better facilitate the diffusion of knowledge and processes, and thus the eventual transition to low carbon technologies. The framework has helped identify a diverse set of system weaknesses in the field of renewable energy innovation, which acts as a blocking mechanism in the transitions to low carbon technologies. For instance, weaknesses in legitimation and knowledge development and diffusion processes have been identified for South Africa.

A central role in understanding renewable energy systems using the TIS approach is given to start-ups and other entrepreneurial activities, with a strong focus on knowledge diffusion processes. High entrepreneurial activity and knowledge diffusion processes mark the case of India, but which is low or non-existent in the case of South Africa. Entrepreneurial activities and knowledge diffusion processes induce the transition to low-carbon technologies, and which policy-makers must facilitate to ease the transition.

Technology and innovation scholars have argued that it is considerably difficult to evaluate the "goodness" or "badness" of a system or a particular structural element or combination of elements without referring to their effect(s) on the innovation process, and thereby the assessment of a system based on functions is more appropriate for policy makers. An understanding of the way these functions either induce or block the transition to low carbon technologies are of importance for policy-makers particularly those contemplating transitions to low-carbon technologies.

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[i] Part of an ongoing research project exploring the transition in the BICS countries to low carbon technologies. As part of the initial exercise this paper investigates two countries – India and South Africa - both heavily dependent on coal as the cheapest and its most path dependent source of power generation.

[ii] Several mechanisms cause increasing returns, such as economies of scale, leading to lower cost, learning-by-using, network externalities, information increasing returns, and technological interrelatedness. Because of these increasing returns a certain technology becomes entrenched while there is no guarantee it is the 'best' one from a broader societal perspective (see Elzen and Geels, 2004).

[iii] Energy intensity is a measure of the energy efficiency of an economy and is calculated in units of energy per unit of GDP

[iv] For details on the innovation systems approach please see Edquist (1997)

[v] Bell and Pavitt (1992) and Bell (2010) distinguishes between production-based and innovation capabilities under technological capability as the capability to carry on producing goods and services with given product technology, and to use and operate given forms of process technology in existing organizational configurations

[vi] Absorptive capacity is a perspective on learning and innovation and is "a firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends. It depends greatly on prior related knowledge and diversity of background. See Cohen and Levinthal (1990) for more detail

[vii] A feed-in tariff (FIT) is a policy mechanism designed to accelerate investment in renewable energy technologies. It achieves this by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each different technology. Technologies such as wind power, for instance, are awarded a lower per-kWh price, while technologies like solar PV and tidal power are currently offered a higher price, reflecting their higher costs

[viii] Local content requirement mandates a certain percentage of local content for wind turbine manufacturing in some or all projects within the country

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