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The role of technology transfer & cooperation for the development of wind power sector in Sri Lanka: a case based approach

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ABSTRACT
Sri Lankan power sector heavily depends on the import of fossil based energy sources and major hydro power plants. Considering the fact that Sri Lanka's hydro power reserves have already been utilized, the country's power sector highly vulnerable to price fluctuations in the imported fossil energy sources. Recent wind-mapping studies claim that the country possesses several areas estimated to have good-to-excellent wind resources. However, given such a backdrop, Sri Lanka is still lacking in its capability to maximize on the real potential of wind power based electricity generation. Accordingly, the objective of this research is to study the technology transfers and collaboration in the wind power sector in Sri Lanka and to identify a directional strategy to foster the development of wind turbine and components industry in the country. In order to effectively answer the stated research questions a qualitative approach was adopted. A comprehensive literature review followed by two case studies pertaining to the wind power sector in Sri Lanka were studied. The first case represented typical technology transfer approach in many developing countries, in which country acquired the wind technology through international trade. The second case is an example of technology licencing and study reveals that such integrations have subsequently created opportunities for more local value addition.

Keywords: *Case study, Renewable energy, Sri Lanka, Technology transfer, Wind power.*

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I. INTRODUCTION

Similar to many other developing nations, the Sri Lankan power sector also primarily depends on the import of fossil based energy sources. This unsustainable dependency has resulted in several adverse consequences impacting on the country's economy which subsequently had a negative bearing on the citizens of Sri Lanka. The frequent and extended power cuts during the peak hours throughout the country in the recent past is one such example. As per the statistics divulged by Ceylon Electricity Board of Sri Lanka (CEB), the total power consumption requirement at the end of year 2014 totalled to 12,357 GWh. Meanwhile, from this total power generation requirement, a little in excess of 60% was generated using thermal power sources which include thermal oil and coal. Likewise, approximately 37% of the total annual power requirements in 2014 was generated with the provision of hydro power. Therefore, the above statistics highlight that from the total requirement, nearly 96% of the country's total electricity generation continues to depend on traditional hydro and thermal power sources. The CEB publications further reveals that the contribution of non-conventional renewable energy (NCRE) which comprised of small hydro, wind, biomass and solar solutions only contributed approximately 4% of the total power generation (CEB, 2015).

However, on a positive note, in terms of hydro power electricity generation; Sri Lanka stand tall in comparison to several other developing nations. Meanwhile, considering the fact that Sri Lanka's large and small reserves of hydro power have already been utilized, the country is currently actively pursuing the search for alternative power sources for instance; wind and solar based electricity generation (Withanaarachchi et at, 2015a). Likewise, as an alternative energy solution, wind energy, is considered to be the most economical and widely available option in renewable sources, and takes precedence over all other renewable sources (Moghaddam et al, 2012: 299). Moreover, the wind-mapping studies performed by the US National Renewable Energy Laboratory (NREL) identified that Sri Lanka possesses several areas estimated to have good-to-excellent wind resources, with wind power densities in the range 200 – 600 W/m2 in the north-western and south-eastern coastal regions and in the north-central region, exceeding 600 W/m2 in the central highlands (Ratnasiri, 2008). Having such a wind potential, the country has several advantages in harnessing this source of energy towards generating electricity. Meanwhile, among the many advantages one can identify the creation of employment, local value addition, enhancing the export market and related opportunism are just a few such benefits.

However, given such a backdrop, Sri Lanka is still lacking in its capability to maximize on the real potential of wind power based electricity generation. Meanwhile, as per the statistics of Ceylon Electricity Board, by the end of year 2014 the total installed capacity of wind power in Sri Lanka was only 131MW (CEB, 2015). This leaves considerable room for the wind power sector to be developed in the country. Thus in today's context, the technology behind wind energy has evolved so rapidly and the advancements gained by many developed and rapidly developing nations such as China and India are excellent examples for developing countries such as Sri Lanka. The above two countries have recognized Technology Transfer as a cornerstone in reaching a global solution to climate change.

Nevertheless, the prominence of technology transfer from a development standpoint is not a new phenomenon. In 1975, Mansfield (1975) indicated that, "One of the fundamental processes that influence the economic performance of nations and firms is technology transfer. Economists have long recognized that the transfer of technology is at the heart of the process of economic growth, and that the progress of both developed and developing countries largely depends on the extent and efficiency of such transfer. In recent years' economists have also come to realize the important effects of international technology transfer on the size and patterns of world trade" (Ramanathan, 2008).

As per the above statement, technology transfer and collaboration cannot only be limited to wind or renewable energy generation. Rather in today's context, technological innovation and management is considered to be a key driving force in the development of an economy. The economic progression of both developed and developing countries depends upon it (Ali, Muhammad and Park, 2011). For instance, Sri Lanka as a nation, have benefited immensely in several sectors through effective technology transfer. Hydropower sector is one such example, where the country has been blessed with local capabilities to export hydro power turbines and relative components to several countries in Africa and Asia. However, in comparison to the hydro power sector, the country continues to lack in its technological capability in the wind power sector. For instance, the country lacks experience to enhance their wind power generation capabilities and the absence of proper assimilation of technology transfer procedure may have been the cause for such impediments. A fundamental point when understanding how technology is acquired is that technology is not merely a physical aspect but also comprises knowledge embedded in hardware and software. The acquisition of technological capability is therefore not a one-off process but a cumulative exercise in which learning is derived from the development and use of technology.

Based on such a back drop the primary objective of this research is to study the technology transfers and collaboration in the wind power sector in Sri Lanka, and to identify a directional strategy to foster the development of wind turbine and components industry in the country.

II. METHODOLOGY

As stated in the objectives of this study, measuring technology transfer is naturally difficult due to its inherent qualitative nature. Therefore, the transfer of technology is not physically embedded in the imported or manufactured goods. Rather it's a process which encompasses the knowledge and related technological capabilities which require to be transferred along with the process (World Bank, 2008). In that sense measuring and evaluating technology transfer should be conducted in a qualitative manner.

Accordingly, in order to effectively answer the stated research questions a qualitative approach will be adopted. Thus a comprehensive literature review on local and international publications with respect to the wind power industry will be conducted to understand the current scenario of wind power generation both globally as well as of the local context. Meanwhile, two case studies pertaining to the locally developed technologies and technology transfers in the wind power sector in Sri Lanka will also be used to elaborate the practical scenario of such developments. As per Pueyo et al (2011), case studies depict the actual technology transfer process and provide a focused, localised, empirical and qualitative approach in understanding the variables that govern successful technology transfer (Pueyo et al, 2011). In conclusion, experts representing governmental organizations, NGOs, Independent Power Producers (IPPs) and Scholars were interviewed to identify the directional strategies to foster the wind power sector of the country.

III. LITERATURE REVIEW

3.1. Definition for Technology

Prior to undertaking discussions on the essence of technology transfer, it is vital to understand what is technology due to its broad definition. Scholars, such as R. Jones, have defined technology as the way in which resource inputs are converted into commodities (Jones, 1970), while others, such as Burgelman et al. (2004) define technology as, "'the theoretical and practical knowledge, skills, and artefacts that can be used to develop products and services, as well as their production and delivery systems. Technologies can be embodied in people, materials, cognitive and physical processes, plant, equipment and tools. Key elements of technology may be implicit, existing only in an embedded form (like trade secrets based on knowhow) and may have a large tacit component". Such diverse definitions indicate that a universally shared definition has not yet been identified, due to the rapid evolution of technology itself.

3.2. What is Technology transfer?
The broad definitions of technology has resulted owing to the need of a broader definition for the term 'technology transfer'. For example, Schnepp et al (1990) define technology transfer as ''... a process by which expertise or knowledge related to some aspect of technology is passed from one user to another for the purpose of economic gain''. In contrast, scholars such as Munir (2002) defined technology transfer as the process of managing the acquisition and incorporation of technology from a source, external to the firm. Going beyond such a broad definition the Intergovernmental Panel on Climate Change (IPCC) report on Methodological and technological issues in technology transfer define technology transfer in terms of a set of processes ''covering the flows of know-how, experience and equipment, for mitigating and adapting to climate change amongst different stakeholders such as governments, private-sector entities, financial institutions, non-governmental organizations (NGOs) and research/education institutions'' (IPCC, 2000).
The above definitions of IPCC on climate change technology transfer indicate the importance of green technologies for the developing world. Therefore, when considering the recent developments in developing countries it is evident that energy is the basic need for the continuity of economic development and human welfare of these nations. More specifically, electrical energy is one of the crucial forms of energy used by humans in manufacturing products and providing service. Resultantly, the rapid developments taking place in developing nations have resulted with higher per capita electricity usage (Moghaddam et al, 2012).

3.3. Components of Technology Transfer
However, rising greenhouse gas (GHGs) emissions and associated environmental concerns indicates that the developments in these developing countries will not be sustainable if these countries simply follow the historic polluting trends of industrialised countries. Meanwhile, the available literature signifies that in order to achieve a sustainable economic development, developing countries require assistance to enhance human capacity (knowledge, techniques and management skills), with the assistance of appropriate institutions and networks, along with the acquisition and adaptation of specific hardware (Karakosta, Doukas and Psarras, 2010). However, the stated components are based on the transformation of certain resources to one another guaranteeing greater value form which will satisfy human needs and wants. Amilth and Sharif (2007) describes that there are four major components of technology required to implement the above transformation namely; Technoware: Object-embodied physical facilities, Humanware: Human oriented factors, Infoware: Information and knowledge, and Orgaware: Organization-embodied operational schemes. Similar to Sharif's classification Leonard-Barton (1992) has also suggested four dimensions (or assets) that comprise of the knowledge-set required to promote technological innovation. The four dimensions comprises of; knowledge and skills embedded in employees (Humanware), Technical systems: Knowledge embedded in technical systems (Technoware), Managerial systems: Formal and informal ways of creating knowledge (Orgaware), and Values and Norms: traditions from the founders (Infoware). With this background the next section of the study provides an overview of the wind power sector in Sri Lanka and the country's actual potential in generating electricity.

3.4. Technology transfer process
According to Bennet and Vaidya (2001), there are two types of technology transfer processes: vertical technology transfer and horizontal technology transfer. The vertical technology transfer refers to the technology transferred from research to development to production. It follows the progressive stages of invention, innovation and diffusion. Consequently, the vertical technology transfer can take place within an organization itself or there may be a transitional transaction between, a research institute (such as universities) and a business entity to continue towards commercialisation. On the other hand, in the situation of a horizontal technology transfer technology which has already been commercialized technology is transferred from one operating entity to another. The persistence of horizontal technology transfer is not to pursue commercialization of technology, but rather to publicize the technology and encompass its application into new perspectives.
The transfer of technology can be implemented in different forms and through different channels. Concerning the breadth and depth of the transferring process, there are two main technology transfer methodologies: inter-firm mechanisms and intra-firm mechanisms (Lema and Lema, 2013). The most common form of technology transfer mechanisms constitute of the inter-firm approach comprising of technology licensing, technical agreements and cooperation, joint ventures, turnkey projects, and the direct purchase of capital goods. However, technology transfer mechanisms such as Foreign Direct Investments (FDI) fall under the category of intra-firm mechanisms (Wei,1995). Apart from this market oriented approach, non-market oriented approaches such as cross-border

movement of personnel, meetings, workshops, conferences and other public forums, and open literature (journals, magazines, books and articles) also play a prominent role in transferring technologies to developing countries (Karakosta, Dosukas, and Psarras, 2009).

3.5. Wind power sector in Sri Lanka

The demand for wind turbines and components is driven by the growth in wind power capacity in a country. Growth of wind power capacity of a country depends on several factors such as wind resource availability, policy framework, availability of investors, technology, etc. In terms of resource availability and resource potential a country's optimum natural energy resource next to hydro power is wind (), since our country experiences two Monsoonal winds which span across the country. Meanwhile, the extent of Wind resource in Sri Lanka has been assessed by the National Renewable Energy Laboratory (NREL) and published as a Wind Atlas for Sri Lanka. Based on the published report approximately 5,000km2 of windy areas with a grading of good to excellent wind resource potential is prevalent in Sri Lanka. Therefore, as per the statistics revealed in the report it is presumed that the country is positioned to support in excess of 20,000 MW of potential installed capacity (Wickramasinghe and Narayana, 2014).

However, prior to 1999 in Sri Lanka wind energy solutions were only used in small scale off-grid electricity generation (Such as battery charging) applications and agricultural water pumping solutions (Senanayake, 2009). The first grid connected wind energy system was developed in year 1999 in the southern part of the country as a pilot scale project. This 3MW wind power project consists of five 600 kW wind turbines. In year 2011, the Wind plant operated at a plant factor of 10.1% while in 2010 the plant factor was 11.4% (CEB, 2013). By end year 2014, the private sector had developed wind power plants in and around Puttalam, Kalpitiya and Ambewela areas adding 128MW to the National Grid (CEB, 2015).

Disappointingly, these statistics indicate that the country is not even using one tenth of its wind power potential to generate electricity. Among many other reasons, the gaps prevalent in the national policies promoting renewable energy is one of the key reasons for the lack of progression in the wind power sector of the country. For example, Hohler, Greenwood and Hunt (in Iyare and Moseley, 2012: 282-283) stated that the future of renewable energy is critically dependent on governments in power in developing countries and their policies committed to meet a significant percentage of their energy needs from renewable energy in the medium term. Thus the next section of the study provides an overview of the national energy policies and strategies which has a direct impact upon the wind power sector of the country.

3.6. National energy policies & Strategies of Sri Lanka

The Sri Lankan electricity supply industry was governed and dominated by state sector institutions namely the Ceylon Electricity Board (CEB) and Lanka Electricity Company (Pvt) Ltd (LECO) (Ministry of Power and Renewable Energy, 2016). Despite the Electricity Act being initially enacted in 1950, a clear policy document to govern the non-conventional renewable energy sector in Sri Lanka, was non-existent, until 2008. Ministry of Power and Energy published 'National Energy Policy & Strategies of Sri Lanka' in June 2008 as an extraordinary gazette notification of the Democratic Socialist Republic of Sri Lanka. This is the first document which covers the total spectrum of the energy sector in Sri Lanka at policy level (The Electricity Act, 2009).

The "National Energy Policy and Strategies of Sri Lanka" is elaborated in three sections under the said policy document; namely, "Energy Policy Elements" consists of the fundamental principles that guide the development and future direction of Sri Lanka's Energy Sector, "Implementing Strategies" states the implementation framework to achieve each policy element above, "Specific Targets, Milestones and Institutional Responsibilities" state the national targets, the planning and institutional responsibilities to implement the strategies. In this policy document nine policy elements are identified under the section "Energy Policy Elements". The fourth item under the above policy element is "Promoting Indigenous Resources" which covers the promotion of power generation using indigenous renewable energy sources in Sri Lanka. This highlights the interest of the Sri Lankan government to promote indigenous renewable energy sources to strengthen the energy sector of the country.

Furthermore, under the section "Specific Targets and Milestones", National Energy Policy specifies the target contributions which are envisaged to be met by indigenous renewable energy sources. Accordingly, 10% of the total energy has to be generated using renewable energy sources by the year 2015 (and has already been met). The section that covers the "Implementing Strategies" describes the implementing steps that can be adopted to promote economically viable, environment friendly, renewable energy resources. Further, this section describes the concessionary financing and incentives available for such projects and R&D to adopt new technology developments. One of the implementing strategies comprises of the adoption of new technologies and practices relevant to renewable energy. These include the transfer of technologies and subsequent development of same, to suit our specific requirements.

Meanwhile, literature available on world wind power development highlight the importance of technology transfers in disseminating wind turbine manufacturing technologies in developing countries. Therefore, the next section of the study provides an overview of the global wind power industry and the impact of technology transfer in reinforcing the wind turbine manufacturing industry in immerging economies.

3.7. Technology transfer in global wind industry

Following the Oil Crisis of the 1970s, modern wind energy development initiations commenced owing to an increase in interest in energy security and long-term sustainability in Europe. The basic design since that time has remained relatively unchanged, the "Danish Concept" is a three-bladed gear-driven, fixed speed design with an asynchronous generator. Two Danish companies: Vestas and Bonus (later acquired by Siemens) have historically dominated the large wind turbine market (Avis and Maegaard, 2008).

As of year 2014, the leading countries for total wind power generating capacity per habitant were Denmark (876.8 W per person), Sweden (557.9 W), Germany (499.6 W), Spain (481.5 W), and Ireland (470.1 W). However, as per the latest statistics (by December 2015) China accounted for the largest total installed capacity of 145,104 MW, followed by USA with 74,471 MW, Germany with 44,947 MW, India with 25,088 MW and Spain with 23,025 MW. Therefore, the above statistics indicates that of the total global installed capacity of 432,419 MW, Asia alone accounted for 175,573 MW (40.6%) (GWEC, 2016). Owing to the escalation of wind energy markets, the newly industrialized countries are rapidly becoming important players in the global wind turbine industry by transferring and developing wind power technologies from the west. Meanwhile, as per recent publications, the largest number of the world's wind turbine manufacturers are located in China, Denmark, France, Germany, India, Japan, Spain, and the United States. An increasing number of manufacturers are also located in Brazil and South Korea which signifies the current role being played by the emerging markets as producers of wind technology. Blade manufacturing, for example, has shifted from Europe to North America, South and East Asia, and, most recently, to Latin America to be in close proximity to new markets (REN21, 2015).

Meanwhile, the escalation of publications of successful technology transfer case studies in developing countries signifies the importance of the role of technology transfer and cooperation in fostering the wind power sector in emerging economies. For example, in the early 1980s India initiated the wind power industry by simply importing turbines through international trade. However, by early 2000 several globally leading wind firms had initiated foreign direct investments in India, including Vestas, Games and Enercon. Currently, the Indian wind energy industry have moved beyond international trade and FDIs to joint venture and licencing agreements to immerge as a global leader of the wind turbine industry (Withanaarachchi et al, 2015b). Similarly, Chinese wind power developments were initiated in the 1980s by importing wind turbines and components to their local market. Turbines were imported from Europe, primarily through bilateral aid projects. Encouraged by the government direct market polices, several Joint ventures emerged between European wind turbine manufacturers and local (Chinese) wind power producers (E.g. Joint venture agreements between Nordex – Germany and Acciona Energy – Spain with Chinese Aero Engine Corporation). Meanwhile, at present supported by government policies, the majority of Chinese wind manufacturers produce wind turbines based on license agreements with foreign technology developers (Lewis and Wiser, 2007).

The above examples exemplify that Sri Lanka could also adopt a similar approach to strengthen the local wind power industry. The gradual steps taken by China and India have helped the two countries to reinforce their technological capabilities over a period of time (Withanaarachchi et al, 2015b). Thus, the following section of the study presents two Sri Lankan examples pertaining to technology transfers of the wind power sector in order to demonstrate the applicability of such an approach in the local context.

IV. WIND POWER TECHNOLOGY TRANSFER – SRI LANKAN EXAMPLES

Meanwhile, the evaluation of actual scenarios is one of the best methods to study the technology development and transfer in wind power industry. The following practical case describe two different perspectives related to wind power technology development and transfer in Sri Lanka.

4.1. Case 01: The story of first commercial scale wind power project in Sri Lanka

Seguwantivu wind power project is the first commercial scale grid connected wind power project in Sri Lanka. The plant capacity comprises of 10MW and it is located in the Mullipuram area in the Puttalam district. The project owner is Seguwantive Wind Power (Pvt) Limited which is a company incorporated by local investors. This geographical area is considered to be one of the best locations for wind power projects in Sri Lanka according to the wind resource assessment conducted by NREL (Elliott et al. 2003). It is classified under class 5 (Excellent) of the wind power classification of Wind Resource Map of Sri Lanka. The plant is situated alongside

the Puttalam lagoon. It covers a strip of land to the extent of 1.6km in length and 50m in width. In this strip 12 numbers of wind turbines have been installed in a single row with a gap of 133m between each unit.
The total annual energy generation was estimated at 25.2 GWh/annum. Based on this energy output, the income for the project has been calculated and subsequently a financial feasibility was conducted by the company using above income and other financial factors such as costs, debt to equity ratio, interest rates, taxes, etc. At the conclusion of the feasibility study, the design was constructed by the turbine supplier (Gamesa® - Spain). According to the design 12 such turbines were planned to be installed under the project.
This first commercial scale wind power project underwent several phases to reach its current operational stage. The respective phases comprise of project approval phase and project construction stage. The project approval comprises of obtaining 24 approvals from different governing bodies in Sri Lanka. Table 01 provides the key approvals obtained by the project.

Table 01: Approvals Required to Develop a Wind Power Project in Sri Lanka

Approval	Approving Institution
Provisional Approval	Sri Lanka Sustainable Energy Authority (SLSEA)
Letter of Intent	Ceylon Electricity Board (CEB)
Tax exemptions	Board of Investment (BOI)
Environmental Clearance	Central Environmental Authority of Sri Lanka/ Provincial Environmental Authority
Land Lease Clearance	District Land using Committee/ Sri Lanka Survey Department/ Forest Department/ Wildlife Department/ Irrigation Department/ Agrarian Services Department/ Archaeological Department/ Provincial Land Commissioner/ Coast Conservation Department
Generation License	Public Utilities Commission of Sri Lanka (PUCSL)
Air Clearance	Civil Aviation Authority of Sri Lanka
Energy Permit	Sri Lanka Sustainable Energy Authority (SLSEA)
Power Purchase Agreement	Ceylon Electricity Board (CEB)
Clearance	Ministry of Defence, Public Security, Law & Order

4.2. Case 02: International Wind Turbine Technology Transfer and Manufacturing Wind Turbines Locally

This study pertains to a local company who had invested on a wind turbine manufacturing facility in the central hill country of Sri Lanka by acquiring technology from a Danish based wind power development company named Xmire. Xmire is a Danish wind turbine designer group comprising of a highly specialized engineering bureau and companies with broad experience in terms of design, development and implementation of wind turbines. They delivered the overall system lay-out, component analysis and selection, load simulations, analysis of vibrations, control systems for wind turbines and documentation for certification. Most of Xmire's projects are driven based on the requirements of local and national standards. Designs are based on distinguished models, but they are adapted to meet the needs of the local manufacturer. The base concept allows for a choice of different components from specialized sub-suppliers depending on their availability. Therefore, local sub-suppliers can be involved. Thus in general, Xmire designs are unique for each customer (Anon, 2016).
The site that was selected for this wind power project was located in Balangoda in the Rathnapura district of Sri Lanka. Despite this site being located in the central part of the country, it is well known that the area contains a higher wind potential from early days. For instance, Sri Lanka experiences two main wind climates, namely the South-Western monsoon (May-August) and the North-Eastern monsoon (October-December). Archaeologists have proven that iron smelting was initiated in the past, by using South-Western monsoonal wind power, instead of using the bellow to pump air to smelting furnaces. This technology had been widely used during the period 300-200 B.C. in the Balangoda district, recording Sri Lanka to be the first country to utilise wind energy for productive work (Juleff, 2003).
Based on the agreement between the local partner (technology transferee) and the Danish company Xmire (technology transferor), the engineering and designer knowledge was transferred gradually. Primarily, Xmire had designed a suitable wind turbine for the selected site by studying and analysing the wind profile and other environmental and physical factors of the site. Subsequently these designs were transferred to the local company supported by relevant documentation, consultancy and training to manufacture the wind turbines locally. However, the main challenge of this project was the accessibility to the site due to the existing narrow road and geographical constraints such as the hill country. Therefore, in order to overcome this challenge, the manufacturing facility was located at the site itself, enabling them to install and test the performance of the wind turbines at the same site while the manufacturing was on-going. The Xmire trained the local staff and equipped

them with the necessary machinery to manufacture turbine blades, hub, electrical panels and certain mechanical components. Whilst certain key components such as the generator and the control system were imported from the supplier (Xmire) several other components such as transformer and cables were purchased from local suppliers.

In the above scenario, as the technology transferor Xmire provided their services to the Sri Lankan partner (technology transferee) in three stages, namely: design, training, and expert assistance. At the design stage, Xmire assisted with aero elastic load calculation, finite element calculations including technical documentation necessary for manufacturing, erection, commissioning, general maintenance and certification. Meanwhile, the necessary skills required to manufacture key components were provided to the local staff through several training secessions. And finally as an expert who has been in the wind industry over 30 years the company assisted the wind power project during the several stages following the construction of wind mill components. Their services are and can be extend to instruction, supervision, training, manufacturing of classified components, mounting and assembly in workshop of tower, transmission, yaw system, hub, hydraulic parts, cabling, including commissioning with testing of the safety system, parameter settings and adaptation of control system.

V. ANALYSIS OF THE WIND POWER DEVELOPMENT CASE IN SRI LANKA IN THE CONTEXT OF TECHNOLOGY TRANSFER AND COOPERATION

The above two wind power development projects provide, a great example for two different approaches where technology transfer was used in the local wind turbine industry. This section of the study is an analysis of the two cases with respect to the mechanism used, the involvement of components of technology that was engaged in this transferring process and essence of horizontal vs. vertical tech transfer for this specific scenarios.

5.1. Analysis of Technology Transfer mechanism

As stated earlier (in literature review) technology can be transferred under different mechanisms. However, in the real world, the distinction between these different mechanisms may be unclear. Thus for operational analysis scholars have established three distinctive parameters to analyse the appropriate mechanism namely: (i) the origin of proprietary technology, (ii) the ownership of the manufacturer and (iii) the location of production. As Table 2 depicts, these variables differ between the five mechanisms.

Table 02: Categorization of technology transfer mechanism based on origin, ownership and production (Source: Lema and Lema, 2013)

Mechanism	Origin of the technology	Ownership of manufacturer	Location of production
International Trade	External to the country	External to the country	External to the country
Foreign Direct Investments	External to the country	External to the country	Within the country
Joint Ventures	External to the country	Shared between the two countries	Within the country
Technology Licensing	External to the country	Within the country	Within the country
Local technology development	Within the country	Within the country	Within the country

Accordingly, the two wind power development cases were analysed as per the three parameters in order to identify the technology transfer mechanism that was used (Refer Table 03).

Table 03: Evaluation of two wind power development cases based on origin, ownership and production

Wind Power project	Origin of the technology	Ownership of manufacturer	Location of production
Case 01	Gamesa® (Spain)	Gamesa® (Spain)	Gamesa® manufacturing facility in India
Case 02	Xmire (Denmark)	Local Partner (Sri Lanka)	Site in Balangoda (Sri Lanka)

In the first case the wind power turbine technology was initially introduced by the Spanish supplier Gamesa®, and the technology was commercialized and manufactured by the same supplier. Thus the origin and the ownership of the manufacturing facility for the twelve wind turbines took place outside the country (i.e. in Spain). To cater to different markets, Gamesa® has their manufacturing plants in Spain, India, China and Brazil. Thus in the first instance (Case 01) wind turbine components were manufactured in one of their Indian facilities. This indicate that the location of production also falls under the category of 'External to the country'. Based on stated variables the mechanism used in transferring the wind turbine technologies to Sri Lanka in the first case can be described as International trade. Resultantly, only a nominal component of technology and knowledge transfer was transferred to the host country (or to Sri Lanka). Since this was the first commercial scale wind power project in Sri Lanka, local engineers did not have the necessary technological capabilities to engage in the development process. Therefore, the majority of operational and maintenance know-how, was transferred to the transferee via training and consultation.

In the second case the original design of the wind turbines was compiled by Xmire in Denmark. However, these design parameters along with the technological skills to manufacture the turbine blades, hub and a few other mechanical components were transferred to the local partner through training and consultation. Thus most of the key components were manufactured by the local partner at a site located in Balangoda, Sri Lanka. However, whilst a few key components were imported to Sri Lanka from the Danish supplier, the final assembly was implemented by the technology transferee. Thus the ownership of the manufacturer occurred within the country and the location of production was also inside Sri Lanka. Thus based on origin, ownership and location of production the mechanism used in transferring the wind turbine technologies to Sri Lanka in the second case can be described as technology licensing. As per Pueyo et al (2011) technology licensing is one of the most common mechanism used in climate change technology transfer. However, in order to transfer the technology through the provision of a licensing mechanism the transferee requires to be equipped with considerable technological capabilities. In this particular case the local company (or the transferee of the technology) possessed substantial experience in the hydro power sector coupled with technological knowledge on hydro power turbines. Resultantly, the above capabilities of the transferee enabled the successful transfer of the engineering knowledge from the technology supplier.

5.2. Analysis of the components of Technology that is been Transferred

As discussed earlier (in literature review) during the technology transfer process, the term "technology" is used in the context of four components, namely: technoware, humanware, infoware and orgaware. This section of the study endeavours to provide a detailed evaluation of the above four components with respect to the two wind power development projects in Sri Lanka.

Table 04: Evaluation of two wind power development cases based on components of technology

Wind power project / **Components of technology**	**Case 01:** First commercial scale wind power project in Sri Lanka	**Case 02:** Technology licencing agreement to manufacture wind turbines locally
Technoware	Almost all the key components of the wind turbines were imported through the supplier. The key components comprise of: blades, gear box, generator, controller, and the tower.	Imported Components: generator, control system Locally Manufactured Components by Tech Transferee: turbine blades, hub, electrical panels and some mechanical components Locally Purchased Components: transformer, cables
Humanware	• The foreign engineers who manufactured the components of wind turbine. • The trained foreign technical staff who undertook the installation. • local technical staff who assisted in the installation process. • Other staff such as local engineers and the management, local O&M staff.	• Experts from Xmire (Tech transferor). • Trained local engineers to do the manufacturing. • Trained local maintenance staff.
Orgaware	Sustainable Energy Authority of Sri Lanka, Ceylon Electricity Board, District Land using	Other than the local technology transferee and the Danish company Xmire® (technology transferor) the following

	Committee Civil Aviation Authority of Sri Lanka Coast Conservation Department Central Environmental Authority of Sri Lanka Public Utilities Commission of Sri Lanka Board of Investment of Sri Lanka Respective local governing authorities	parties also engaged in the technology transfer process. • Local component suppliers (Lanka Transformers, Cable companies, etc). • Local governing authorities (Such as SLSEA, CEB, PUCSL, local authorities, etc...).
Inforware	Wind speed data of the site, Wind turbine design information, data on wind frequency distribution, data on energy yield of the project	• Design details (such as overall system lay-out, component analysis and selection, load simulations) • Design specification details • Operating Instructions • Maintaining instructions

5.3. Vertical Vs. Horizontal Technology transfer

Vertical and Horizontal technology transfer indicates the direction in which the wind power technology is transferred. Specifically, horizontal technology transfer is the transfer of a commercialized or operational (usually mature) technology from one organization in a specific socio-economic context to another organization in a different socio-economic context, through intra-firm, cross-industry, or cross-border channels. And vertical technology transfer refers to the transfer of technology from basic research to applied research to development and then to production. The following section of the study provides an analysis of the two scenarios to distinguish between the two technology transfer approaches.

Table 05: Evaluation of two wind power development cases based on direction of technology transfer

Case 01: The story of first commercial scale wind power project in Sri Lanka	Technology transfer involved in wind power development project can be primarily categorized into six stages. Commencing from R&D, commercialization of technology, component manufacturing, full turbine manufacturing, installation and finally the operation and maintenance of the machinery. In this first commercial scale wind power project the first four steps (from R&D to final turbine manufacturing) was implemented by the foreign supplier. Resultantly wind turbines which were already developed by the transferor were installed in Sri Lanka with the assistance of the local engineers. Though there have been certain adjustments in the wind turbines to conform to local conditions the local value addition has remained at a relatively nominal level. Hence this case is an example in which technology already established has been transferred from an overseas destination to Sri Lanka. Thus the technology transfer process that was used in this case can be identified as the '**Horizontal transfer of technology**'.
Case 02: International Wind Turbine Technology Transfer and Manufacturing Wind Turbines Locally	In this wind power development project, the technology was transferred to Sri Lanka in gradual steps. The technology supplier conducted the research and development, followed by the commercialization of technology. Subsequently, the technology has been transferred to the local partner in different forms. Primarily, the knowledge pertaining to component manufacturing was transferred to local engineers through training. Resultantly, based on this knowledge transfer, local engineers manufactured turbine blades, hub, electrical panels and certain mechanical components in Sri Lanka. Subsequently with the use of these key components and the utilization of the imported generator and the control system, the local company manufactured the full turbine. Final installation was also undertaken by the local engineers with the assistance of the foreign supplier. Today the operation and the maintenance of the wind power project is implemented by local engineers. The above scenario indicates that this wind power development project followed the progressive stages of invention, innovation and diffusion. Thus the technology transfer process that was used in this instance can be identified as the '**Vertical transfer of technology**'.

VI. DISCUSSION AND CONCLUSION

The above cases represent two different scenarios pertaining to the wind power technology transfer in a developing country. As per the above analysis, in the first case (the first commercial scale wind power project in Sri Lanka) the country acquired the technology through international trade. Further, in this scenario technology transfer was limited to dissemination of mature technology, where the technology supplier transferred the minimum level of know-how on operations and maintenance to the transferee. This horizontal technology transfer reflects the most common form of technology transfer approach used in Sri Lanka in terms of climate change technologies. However, in the second case wind turbine technology was transferred to Sri Lanka through a licencing agreement. In this approach, the technological know-how was transferred to the Sri Lankan engineers largely through training and consultation. Further by working along with the Danish experts, the host country (or Sri Lankan company) managed to gain the relevant knowledge, which transferor (Xmire) have gained through years of experience.

When transferring nationally beneficial technologies, it is prudent to understand that the environmentally sound technologies are not just individual technologies, but a total system which includes know-how, procedures, goods and services, and equipment as well as organizational and managerial procedures (Philibert, 2004). The two cases highlighting the situation of wind power development in Sri Lanka depict that, the country has a vast potential to harness the wind resources distributed along the costal line as well as the central hill country. However, the country is still lagging in optimizing the wind potential energy for electricity generation due to several reasons. Primarily the national grid which has been designed to absorb electricity generation via predictable sources (such as hydro and fossil based sources) has certain limitations in absorbing electricity generated via wind power (due to its unpredictable and varying nature). Secondly due to lack of experience, the local technological capabilities in the wind power sector continue to remain at a primary level. Thirdly, despite the country possessing a well-established government institution to assist and govern the wind power development projects, poor interconnection between these institutions has resulted in prolonging the receipt of approvals.

As illustrated earlier, the scenario presented in Case 01 is a typical technology transfer approach in many developing countries. Conversely, by just relying on international trade to acquire key technologies implies that the technology importer and the importing country are largely dependent on purchase options of foreign suppliers. These inputs are mainly those that local suppliers and the technology importer are unable to produce to the required specifications and standards of quality, reliability, durability, and cost. Raw materials, parts, and components have to be imported continuously to maintain the proper functioning of the imported technology. These required imports are likely to drain the scarce foreign currency (Wei, 1995). Thus, when transferring these technologies to local economies (especially developing countries) it is prudent to ensure the efficient operation of the acquired technology and linking the initially acquired technology into the wider structure of the economy through forward and backward linkages to other areas of production. However, in the second scenario, a wider set of stakeholders have benefitted through such integrations which subsequently created opportunities for more local value addition. For instance, through technology licensing agreements, several local industries comprising of steel fabrication, fiberglass, equipment (or machine) supplying, cable and electrical equipment supplies, and logistic services received the opportunity to embrace their presence in this national project.

The above two cases indicate the advantages Sri Lanka possesses as a developing country to foster the wind power industry through proper technology transfer and cooperation. However, such a technology transfer attempt should not be merely restricted to international trade. However, through proper management of technology by blending innovation and creativity to transfer technology can offer immense opportunities to Sri Lanka. The models of technology innovation in developing countries are based on several stages, for example, imitation stage, improvement stage and innovation stage (Ali, Muhammad and Park, 2011). In that sense Sri Lanka still in imitation stage with minor technological adaptation capabilities. Thus the time has come for us (Sri Lankan) to follow other rapidly developing nations (such as China, India, South Korea, and Taiwan) and proceed for the next stages of the development cycle to foster the wind power industry.

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