THE REAL COST OF WIND ENERGY

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Abstract

South Africa needs to consider renewable sources of power especially because it relies so heavily on fossil fuels. Wind energy is a strong possibility, characterised by large cost reductions over recent years. Based on US Gulf Coast plants and adjusted to South African conditions, costs by EPRI (2010) were estimated albeit within a margin of error. Although data assumptions are discussed, further work would be required to evaluate their relevancy for the cost estimates. Findings indicate that wind power is still more costly than conventional coal techniques, even when coal plants employ expensive pollution abatement technology.

1. INTRODUCTION

THE ENERGY CRISIS OF SOUTH AFRICA in 2008 highlighted the supply constraints of a country in dire need of additional power infrastructure. Eskom responded with new generative capacity, mainly taking the form of coal-fired intensive technology (Hallowes, 2009). Medupi and Kusile are two of the new fossil fuel plants being built to relieve supply pressure, producing around 4800MW each. Coal power accounts for about 85% of the countries' total licensed capacity, favoured for its historically cheap fuel prices due to low-cost mining practices. However, coal plants are also very dirty forms of producing power, emitting nitrous oxide (NO_x), sulphur dioxide (SO_2) and carbon dioxide (CO_2). Local and international pressure is being felt by Eskom to curb fossil fuel use and to increase its portfolio of renewable technology. Wind energy is one of the solutions being considered. Characterised by large cost reductions over recent years, wind farms are quickly becoming competitive with coal power. The cost of energy is an important consideration, especially in South Africa's case, with large poor communities relying on cheap power for basic service provision (Winkler, 2005). Therefore, Eskom must invest in renewable technology that will be able to contend on some level with coal power. While a REFIT tariff of R1.25\kWh has been implemented to encourage investment, subsidization may eventually be very costly for the government to maintain if renewable energy penetration rates become high (Grocott's Mail, 2009). This paper thus analyses wind power as a viable competitor by comparing the levelized cost of electricity (LCOE) for each technology. The Electric Power Research Institute's (2010) report provides estimated LCOE's for South Africa. As these figures are based on US Gulf coast power plants assumptions were made for adaption to RSA conditions. These assumptions are scrutinised to test if they hold under qualitative analysis. Where deficiencies in the data are found, suggestions for adjustment will be made for the respective LCOE's. This paper does not seek to quantify the extent of inaccuracy in the cost estimates, but instead exposes the limitations inherent in the assumptions and thus the reliability of the data.

2. THE LCOE METHOD OF PLANT COST

The energy industry uses a levelized cost of electricity framework to determine unit costs of different methods of energy generation (IEA, 2010: 33). Expenditures during the life cycle of projects are added together and discounted at a predetermined discount rate. The choice of the discount rate has a crucial impact on the results of the LCOE's, favouring technologies which require large initial capital outlays if the interest rate is low while projects with smaller capital outlays are favoured if it is high. The European Wind Energy Association (EWEA, 2009: 22) argues that if higher discount rates are normally applied to riskier investments in financial markets, this should also be common practice when considering power plant investments. However, the LCOE model does not consider risks involved with the day to day operation of the different plants (IEA, 2010: 33).

Risks for coal plants tend to be much higher than those associated with wind farms, for example one of the most important costs to consider when comparing fossil fuel plants to renewable energy is fuel costs. Wind farms have no fuel costs as power is derived from the wind. Thermal plants on the other hand, depend on fuel and are therefore "expense intensive technologies" (EWEA, 2009: 21). The fuel component in cost analysis present the problems of uncertainty and unpredictability, as costs are subject to fluctuation, given market conditions at different periods. Current LCOE analysis normally does not take these fuel price changes into account which means that representative costs used for coal plants studies are susceptible to a high degree of error (EWEA, 2009: 21). This can be especially costly if the majority of the licensed capacity is generated by coal sources.

It is also important to note that there are a variety of other costs to consider for projects, all of which cannot realistically be included in the model. Thus often the LCOE formula is configured to the needs of the particular organisation or body as required. Only factors that are considered the most important, normally 'internal' costs are used for these projects. Typical factors considered in an LCOE analysis include investment (overnight capital costs) costs, fixed operation and maintenance (O&M) costs, variable O&M costs, fuel costs, decommissioning costs, carbon tax, income tax and total plant output for a given year (EPRI, 2010 and IEA, 2010). Many of these variables already incorporate costs involved with the plant. For example, fuel costs should reflect the costs to mine and transport coal to plants, while overnight costs include equipment, materials, labour used in construction, engineering and contingencies. Therefore simplifying the model through the use of fewer variables does not imply that results would be any less accurate than one with many. LCOE methodology vitally provides a means to compare costs of different techniques of power generation. Ultimately the end figure is given by the cost per MWh (megawatt-hour) or kWh (kilowatt-hour) and forms the basis for comparison.

The model is also useful in adding negative externality costs associated with the different methods of producing power. For example, a study by Roth and Ambs (2004) included some externalities characterised by each method of producing electricity, using an adapted levelized cost of electricity model. External costs factored into the model included: damage from air pollution, energy security, transmission and distribution costs and other environmental impacts (Roth and Ambs, 2004: 2125). By including these variables, the results were significantly altered in favour of renewable over conventional technologies. The Electric Power Research Institute (2010) research report however, does not include externalities and therefore only analyses the "busbar" (plant level) costs between wind turbines and coal power plants.

The time period for each technology is based on the projected lifetime of each mode of producing power. Coal power tends to have a relatively longer lifetime of between 30 and 40 years, while wind power has a shorter lifetime of 20 - 25 years (IEA, 2010 and EPRI, 2010). Another criticism of the LCOE model however, is the lack of consideration given to the intermittency of wind power. Stability and consistency are not taken into account in estimating the LCOE's of the different power generation techniques. Coal plants would be able to supply power consistently, with production stopping only for scheduled maintenance or through lack of fuel. Wind power would be reliant on the wind and therefore, would need some form of backup system to assist in reliable energy provision during periods of low wind speed.

To mitigate problems of instability and inconsistency, DeCarolis and Keith (2006) studied the effect of dispersing wind farms over many different areas, mixing these systems with backup storage along with an existing generation mix of gas turbines. Gas power plants are favoured over nuclear and coal plants as the ramping rates differ. Ramping rates refer to the amount of time it takes to activate dormant power generation from existing plants. As start-up times tend to be longer in coal and nuclear plants the result is a higher cost of intermittency (DeCarolis and Keith, 2006: 397). Gas plants were found to have the fastest ramping rates, but would not be viable as South Africa lacks any significant gas reserves. Importing gas would not be economically feasible and would work to raise overall LCOE's. Building storage options such as compressed air energy storage (CAES) and pumped hydro would also incur large costs which would need to be factored into the LCOE equation. Alternatively, diversification is found to hold the lowest risk. Dispersing wind farms would increase the chances of wind blowing at the sites as each area would have unique weather conditions, acting to reduce overall intermittency (DeCarolis and Keith, 2006: 402). For the purposes of this paper, backup solutions are ignored, while the busbar LCOE's for wind turbines and coal plants are the primary focus.

3. DATA

Coal power plants are normally built with more than 1 generator unit and therefore it is appropriate to present the data showing the LCOE's for the various plant sizes. The first plant is pulverized coal without flue gas desulphurization (FGD) technology. FGD equips fossil fuel plants with sulphur dioxide removal technology and is therefore a cleaner but more expensive option (EPRI, 2010). Each generating unit has a capacity of 750MW, therefore a 2 unit plant has a total net capacity of 1500MW, 4 units 3000MW and 6 units 4500MW. The LCOE's for the different plant sizes are listed in table 1 below.

Table 1. LCOE's for coal power with and without FGD technology

	2x 750MW	4x 750MW	6x 750MW
Pulverised Coal without FGD LCOE (ZAR\kWh)	R0.55	R0.53	R0.52
Pulverised Coal with FGD LCOE (ZAR\kWh)	R0.63	R0.61	R0.59

Source: Adapted from EPRI's (2010) Power Generation Technology Data Report for the Integrated Resource Plan of South Africa.

The larger plants have lower LCOE's as economies of scale act to lower project costs. EPRI (2010) attributes this to favourable contracting terms due to all generative units being housed in one facility. The Medupi power station is currently being constructed to relieve electricity supply issues and will comprise of 6x 800MW units with supercritical boilers (ESKOM, 2010). Supercritical boilers achieve higher temperatures and pressure and therefore are more efficient than older technologies (more power generated per unit of fuel used). Similarly, the Kusile power plant is under construction and will have the same capacity as Medupi while being the first coal plant in South Africa to employ FGD technology (SouthAfrica.info, 2008). Thus the LCOE of R0.52 will be used as the representative cost for Medupi while R0.59 will be used for Kusile. While FGD using a limestone forced oxidation (LSFO) wet scrubber removes up to 95% of SO_2 particulate matter, other particulates not captured include CO_2 and Nitrous Oxide. SO_2 however has higher immediate human health concerns, especially when emitted from fossil fuel plants and is responsible for causing large scale respiratory disease (World Resource Institute, 1999). CO_2 and Nitrous Oxide on the other hand are mainly greenhouse gasses, abatement of which will only really become important once a tax on these particulates is introduced in South Africa. FGD is included to illustrate a relatively cleaner alternative to unrestrained pollutant coal plants.

Table 2. LCOE's for wind power at different levels of wind quality and farm size (small scale)

Rated Capacity		20MW		
Wind Class	3	4	5	6
LCOE (ZAR/kWh)	R1.05	R0.92	R0.84	R0.75
Rated Capacity		50MW		
Wind Class	3	4	5	6
LCOE (ZAR/kWh)	R0.99	R0.87	R0.79	R0.71

Source: Adapted from EPRI's (2010) Power Generation Technology Data Report for the Integrated Resource Plan of South Africa.

Although there has been limited wind farm development in South Africa at present, the projects that have been implemented tend to be small. Operational projects in South Africa currently fall below 10MW, the most well known being the Darling (5.2MW) and Klipheuwal (3.2 MW) wind farms, both located in the Western Cape (EngineeringNews, 2007 and Central Energy Fund, 2008). Table 2 represents the typical costs faced by utilities and independent developers for smaller wind farm projects in South Africa. A wind class of 3 is equal to speeds of 7.2 meters per second (m/s), class 4 is 7.8 m/s, class 5 is 8.3 m/s and class 6 is 9 m/s. Higher wind classes yield lower LCOE's which is to be expected. The wind classes depict the quality of resource present at a given time and location. For example, although wind is not constant at any site, there will be a significant difference in quality of wind resource depending on where wind farms are situated. Thus good sites tend to yield higher wind classes more often than poor ones. What makes estimating LCOE's difficult for wind farms is the variability of the resource.

On average, costs are about 5c/kWh less for 50MW compared to 20MW wind farms as economies of scale reduce overall operation and maintenance costs. However, these small scale wind farms cannot compete on cost grounds with a coal plant of Medupi's size which yields a cost of 19c/kWh lower than a 50MW wind farm. Thus larger wind farm projects should be favoured by Eskom and independent power producers.

Table 3. LCOE's for wind power at different levels of wind quality and farm size (large scale)

Rated Capacity		**100MW**		
Wind Class	**3**	**4**	**5**	**6**
LCOE (ZAR/kWh)	**R0.96**	**R0.84**	**R0.76**	**R0.69**
Rated Capacity		**200MW**		
Wind Class	**3**	**4**	**5**	**6**
LCOE (ZAR/kWh)	**R0.92**	**R0.80**	**R0.73**	**R0.66**

Source: Adapted from EPRI's (2010) Power Generation Technology Data Report for the Integrated Resource Plan of South Africa.

Table 3. shows the costs associated with large scale wind farms of 100MW and 200MW. Although the 200MW wind farm is not cost competitive with a coal plant with 6 units, if FGD technology is employed (like that of the Kusile plant), figures become much more closely aligned, with a small difference of 7c/kWh. Judging from these figures, wind energy would only become cost competitive with pulverized coal FGD, once the capacity exceeds 400MW. A large scale wind farm is being proposed for the Eastern Cape by a South African renewable energy company (Rainmaker Energy), which could have a capacity of 550MW (Engineering News, 2010). Depending on the site, this wind farm would potentially yield lower LCOE's than the Kusile plant, but not the Medupi plant. Importantly, cost figures discussed for wind assume that the wind blows continuously at a class of 6, which is not realistic. Instead, the wind resource will be subject to fluctuation, creating higher LCOE's. For example, a wind farm with a

capacity of 200MW may be subject to a cost fluctuation of 26c/kWh. The same is not true of coal plants, which would be able to operate at full capacity 85% of the time (EPRI, 2010 and IEA, 2010). The 15% that the plant does not operate is normally taken up by O&M and possible retrofitting.

The EPRI (2010) report states that O&M being performed on a wind turbine will not disturb the rest of the wind farm's overall capacity to generate electricity. The implication of this finding is that the opportunity cost of performing maintenance on a wind farm will be less than that of a coal plant. If three wind turbines need repairs, a total of 6MW (assuming each individual turbine is 2MW) would be omitted from the power supply. Coal plants on the other hand would need to shut down a unit consisting of 750MW, resulting in a much higher cost. However, because there is no variability outside of the necessary maintenance time, coal power is therefore more reliable than wind, providing power more consistently, which is very important for economic considerations.

4. DISCUSSION OF ASSUMPTIONS

Data is taken from an EPRI (2010) report, which investigated possible energy solutions for the South African Department of Energy for use in the Integrated Resource Plan (IRP). It is important to note that the data is based on energy plants located in the US Gulf Coast and adapted to South African conditions, while working on various assumptions (EPRI, 2010: 10). For capital costs, total plant and operation and maintenance costs during construction are compiled into one figure, called overnight costs. Essentially, overnight costs assume that the plant is built overnight and therefore "does not include interest and financing costs" normally incurred during the construction phase (EPRI, 2010: 69). Factors included in this figure are equipment, materials, labour, engineering and contingencies. Materials used in construction were found to cost similarly in both the US and South Africa, due to South Africa's cheaper raw materials being offset by relatively higher production cost and lower worker productivity (EPRI, 2010: 70). As power plants require specialised labour expertise, materials and equipment for construction, a certain percentage of these factors would have to come from abroad, affecting the costs for each respective plant. While many of the materials could be produced locally, in some cases it would be cheaper to import these which is a valid assumption to keep LCOE's as low as possible.

Based on the new Medupi Power Project, EPRI (2010) estimated that 35% of the labour, materials and equipment for a new pulverised coal plant construction would have to be imported, while the remainder would be sourced locally. Wind turbines on the other hand would require 70% of labour, materials and equipment to be imported, reflecting South Africa's relative inexperience in wind farm construction (EPRI, 2010: 71). Specialised labour in electrical engineering is in short supply in South Africa as outlined in the National Scarce Skills List (Department of Labour, 2006: 7). A report by the South African Department of Labour (2008: 54) further found that high level (and some low level) labour geared towards the energy sector were the primary gaps in the labour market. This was especially the case for labour specialising in renewable energy, where it was found that only 100 graduates qualify annually (Department of Labour (2008: 54). EPRI

(2010: 71) has accounted for these shortages by assuming that of the local labour, materials and equipment used in the plant (30% in total), only 25% of this total would constitute labour.

As data estimation does have some degree of error, due to different conditions each plant faces, EPRI (2010) calculated the variation present in the different technology costs. Coal power and wind power were both classified as "mature" technologies, denoting that significant market experience has been accumulated which minimises the uncertainty to which cost estimates would fluctuate from the base case. In both cases, the degree of error was 15%, falling below the base case and 30% higher than the base case. Plant estimates for Kusile and Medupi were initially R84.4 billion and R78.6 billion respectively in 2007 (Hallowes, 2009: 24). By 2009, the former Eskom CEO, Jacob Maroga, had to adjust the figures upwards to R100 billion for Medupi and R110 billion for Kusile, an average increase of 30%. This was due to contracting costs being higher than the initial estimates predicted, with more revisions being predicted in the near future (Hallowes, 2009: 24). In essence, this demonstrates that estimates can easily be exceeded and therefore only offer a very rough picture of the actual costs involved in any project.

Many studies identify wind power as being a relatively young and immature industry, still in the process of development as seen through the major cost reductions over the recent years (Soderholm and Klaassen, 2006, Ibenholt, 2002 and AWEA, 2005). Thus based on this consideration, it would be prudent to question whether the Electric Power Research Institute (2010) understates the degree of variance present in its assumption for wind plants. While wind power is not a mature technology by any means, the European Wind Energy Association (2009: 21) states that unlike fuel based power generation methods, most of the costs are known "with great certainty", well in advance. The primary reasons attributed to this certainty is due to wind farms' relative capital intensive infrastructure, that it requires no fuel and has low O&M costs. Coal plants on the other hand depend on fuel which is subject to highly variable prices and thus can have a large impact on LCOE's. Recent evidence demonstrates this point well citing South African coal prices during 2009, which were $50 per ton, and quickly rose to $90 per ton in early 2010, an increase of 80% (MiningMX.com, 2010). Thus because of non-present fuel cost considerations, coupled with the relatively cheap O&M costs inherent in wind power generation, a mature rating is appropriate. As was evidenced earlier however, these ratings potentially mean very little in real world scenarios and would significantly affect wind farms LCOE's if contract costs were higher than estimates.

For coal power plants the EPRI (2010), also assumes that coal prices are static for the lifetime of the plant. This assumption is heroic, keeping in mind the volatility of coal prices and the resultant high sensitivity on the LCOE. Risk of this nature should be factored into the costs for coal plants, based on historical trends and future forecasts. There is difficulty in predicting coal prices as market forces work to progressively change demand and supply conditions. What is known with certainty however, is that increasing demand pressures from large developing Asian economies, specifically China and India, will assist to force prices upwards (Bloomerberg, 2009 and ABC News, 2010). This is especially true for the medium term, as world supply is currently constrained. The Royal Academy of Engineering (2004: 5) found that fuels for coal plants can make up to 70% of the total cost of production. Thus coal plant LCOE's need to be revised upwards to account for these fluctuations, making wind farms more cost competitive.

In addition to overnight costs, fixed charges (booked costs) need to be applied to cover revenue requirements related to the borrowing of money, return on equity, depreciation rate of capital, income tax on equity returns, insurance and property taxes (EPRI, 2010: 90). Fixed charges normally also include O&M costs as well as fuel costs, but these were excluded from annual capital requirements calculations. Instead, O&M and fuel costs are labelled as expenses primarily because these charges can be recovered on an "as you go" basis, while the booked costs (those mentioned above) need to be collected regardless of plant use and are therefore considered obligatory (EPRI, 2010: 91).

The financing structure used in the projects, although generally playing a relatively small role in the overall costing of power plants, can still impact significantly on LCOE's. In a study by the National Renewable Energy Laboratory (NREL, 2009), an equity based financial structure contributed to a 20% increase in the overall LCOE when the target internal rate of return (IRR) increased by 40%. Additionally, it was found that financing projects primarily using debt had the highest cost reduction impact on LCOE's. The more debt secured in a given project, the lower the overall LCOE (NREL, 2009). Equity on the other hand was found to be more costly, related to the dividend premiums holders would have to be paid to attract sufficient investment to such a project. Supporting the NREL (2009) findings, McGrattan and Prescott (2003, 392) found that real interest rates for equity are normally about 1% above debt interest rates.

In the study however, EPRI (2010) assigned rates of return which were 4.4% for debt and 4.2% for equity. A lower interest rate for equity is contrary to the findings in the NREL (2009) report, which should take into account the higher cost of equity over debt. The study assumes that 60% of the capital will come from debt while the remaining 40% comes from equity financing (EPRI, 2010: 89). Lower interest rates for debt relative to equity would affect the required capital estimates. Although the exact impact is beyond the scope of this paper, what can be safely assumed is that the LCOE reduction for wind farms would be greater than that of coal plants.

The discount rate applied to all data in the report was 8.6%, which yielded present values according to the lifetime of each technology, coal power having an economic lifetime of 30 years while wind has fewer, around 20 years. Although these lifetime estimates do seem to be lower than many other sources predict, the important factor is the relative age. Coal plants tend to last longer than wind farms, which is accounted for by the age assumptions. The discount rate was then calculated by multiplying the percentage of debt by the cost of debt (interest rate) and adding this to the percentage of equity invested multiplied by the cost of the equity (EPRI, 2010: 95).

The depreciation rates used are based on the lifetime of the plants and the assumption that decommissioning costs will equal zero (salvage gains are exactly offset by site reclamation). Resulting rates are thus 3.33% for coal plants while 5% for wind farms (EPRI, 2010: 92). Once all respective booked costs were calculated, they are added together to get an annual capital revenue requirement, which is the amount of funds needed annually to sustain the plant for the duration of the project in question. Annual charges tend to decrease as the plant is used up and therefore in order to calculate the LCOE for the respective plants, it is important that these rates are converted into a constant rate per kW/h. The formulae $P = 1/(1 + i)^n$ was necessary for this conversion, where "i" is the discount rate and "n" is the number of years in which the project is run.. Essentially, this formula calculates the present values for all the annual capital requirements and converts them into present value capital charges, which were then converted into an equivalent annual payment which could now be used in the LCOE analysis (EPRI, 2010: 96).

Assumptions about plant performance were also made in the EPRI report based on a number of factors. For coal, it was assumed that the plant will be built in Limpopo province near the existing Matimba coal plant, situated close to the South East border of Botswana (EPRI, 2010: 49). Mpumalanga and Limpopo together currently contain 12 of the 13 coal fired plants in South Africa and are responsible for over 80% of the country's coal production (SouthAfrica.info, 2010). Importantly, it is assumed that the site is situated close to the coal mine, removing the need for railroad infrastructure to serve fuel delivery purposes (coal is delivered directly via conveyer belt to the plant). The new Kusile plant will have coal delivered this way while most of the existing plants in South Africa operate in this same regard (SouthAfrica.info, 2008). Road transportation of coal would not be feasible in the long term both because it is expensive and well below 50% of the coal could be transported this way. Railroad is the only viable option, but requires large capital outlays, which would increase the LCOE of coal significantly. Thus 'mine mouth' coal plants have been the practice in South Africa and are important for keeping costs down.

Additionally, dry cooling systems are expected to be used, which removes the need for close by fresh water stocks. Dry cooling was chosen primarily because South Africa is identified as a water scarce country, with estimates predicting water deficits by 2025 (Department of Environmental Affairs and Tourism, 2006: 3). This is especially the case for Limpopo, which is a water scarce region and thus houses the Matimba plant which is the largest dry cooled coal plant in the world (Eskom, 2010). These factors essentially cut the costs associated with infrastructure investment and thus act to lower the overall LCOE. As the location assumptions for coal plants fall in line with current South African practices, it can be concluded that location factor estimates are reasonably accurate.

Wind power is assumed to be located near coastal regions in South Africa, as the wind tends to be cool and dense, thus increasing the quality of the resource (Rehman *et al*, 2003). The windiest regions in South Africa tend to be located in the northwest and southeast coastal regions (EPRI, 2010: 58). 2MW wind turbines are used in this study, with varying quantities being employed for each wind farm. While the EPRI (2010) study analysed three different mast heights (10m, 50m and 80m), only the 80m LCOE is used. The reason for this is that wind speeds tend to increase as mast height increases, thus also improving on wind quality (AWEA, 2005: 1).

As wind farms in South Africa will tend to be utility or investor based, maximizing the wind resource potential is assumed, therefore only the tallest masts will be used. Instead, wind speed is considered the major factor influencing the LCOE, thus positioning wind farms would play the most important role in cost considerations. This assumption correlates with NREL (2009: 13) research which found that technical factors are the most important consideration and should determine whether a project proceeds. Technical considerations include the proposed project site as well as the various cost factors associated with the particular area (connection costs, transportation etc.). The NREL (2009) found that above all other considerations, projects should select sites with the highest wind resource potential as this would impact LCOE's significantly. As mentioned earlier, EPRI has based all wind farms in high resource potential areas, situated near coastal regions. Thus the above assumptions are considered adequate as a basis for the estimated LCOE costs for a South African setting.

Other factors associated with technical costs, such as grid connection and proximity to urban centres, would be important to consider, as these make up a large portion of the cost for construction and future O&M. However, EPRI (2010) has only included the projected plant level costs, leaving out transmission or interconnection costs. While analysing plant level costs is appropriate for the study, independent power producers and utilities should ideally also factor the above mentioned 'external' expenses for the individual plants to gain a true reflection for a particular project. If a power plant has an isolated position, transmission lines, roads and transportation costs of fuel, spare parts and maintenance should be included in the final report. Wind farms would be prone to higher external costs, especially as the number of built increases. Less favourable and therefore more remote areas would need to be developed, increasing the costs for these projects.

It was stated at the beginning of the paper that externalities for wind and coal energy are ignored in the EPRI (2010) report. However, it is worth mentioning that including pollution factors into the levelized cost of electricity would significantly alter competitiveness in favour of wind farms. Roth and Ambs (2004) found that when negative externalities for coal and wind power were included in their LCOE model, coal power cost close to double that of wind plants. Additionally, coal mines have massive environmental costs attached to them as evidenced by recent acid mine water seepage into the Vaal river (AllAfrica.com, 2010). The Vaal river is one of the main supplies of water to the Gauteng area and therefore acid pollution would affect a great magnitude of people, especially considering that the Gauteng province is the most densely populated in South Africa. The point being made is that fossil fuel LCOE's do not take into account the social cost of pollution borne by society. Thus one could argue on these grounds that the LCOE's provided in the EPRI (2010) study understate coal power's real cost.

5. CONCLUSION

Costs were found to be much lower in general for coal plants than wind farms. Estimates show that when large coal plants such as Medupi and Kusile, are used as benchmark comparisons, small scale wind farms battle to compete. This is true even for more expensive fossil fuel plants, like Kusile, which employs FGD technology to reduce SO_2 emissions. However, when wind farm capacity reaches 200MW, the cost difference between a coal plant with FGD is small, around 7c/kWh. Based on this estimate, if generative capacity of wind farms exceed 400MW, LCOE's for wind power should become cost competitive with FGD plants. Keeping in mind international pressure for countries to lower emissions, future fossil fuel plants would probably need to incorporate some form of abatement. Evidence of this lies with the Medupi plant, which was originally designed without FGD, but mounting pressure eventually convinced Eskom to install 3 scrubbers in a total of 6 units (Hallowes, 2009: 15). Thus future fossil fuel plants would probably employ abatement technology of this kind, further aligning with wind plant LCOE's. .

As cost performance for the various technologies were based on US Gulf Coast estimates and adapted to South African conditions, assumptions had to be made. Skills shortages for renewable technology are a reality in South Africa, with necessary supplementation required from oversees. Imported labour would come at a premium and therefore raises the costs of construction and operation of wind farm projects. Although many of the materials for the plants could be sourced locally, it would be more economical to import materials which sell for lower on the international market. Additionally, the technical factors for power plants were found to be well researched reflecting the local circumstances and constraints faced by South Africa.

However, some assumptions proposed by the Electric Power Research Institute (2010) were questionable. Research shows that equity normally pays higher interest rates than debt. As projects were assumed to be primarily financed through debt, LCOE's would be lower than estimated. This is especially true for wind turbine costs, which would fall by a relatively larger amount than coal plants (attributable to its capital intensity). Although EPRI (2010) did include the degree of variability in cost estimation, South African evidence shows that contracting costs could exceed these expectations by a much larger degree than anticipated. For coal plants, static fuel costs are assumed for the lifetime of the project. Evidence finds such assertions to be highly unlikely, with recent coal prices spiking due to increasing international demand. LCOE's for coal plants should therefore be revised to a higher figure to reflect the uncertainty of these prices. Wind farms are not affected by commodity prices, except for materials used in the construction phase of the project. However, build times tend to be fast and does not represent as much of a concern as for coal plants. The main issue for wind plants is the variability in wind and thus estimating true LCOE's, which could vary in the same project by as much as 26c/kWh.

Overall however, results still favour coal power as the cheaper of the two generation mixes. Even if coal power and wind power LCOE's were to take into account the changes suggested in this paper, it is doubtful whether wind power would become competitive. The South African government has introduced a subsidy for renewable energy, which allows wind farms to be viable. At R1.25/kWh, wind farm operators have an incentive to build projects, as cost competitiveness can largely be ignored. A viable alternative could be to undertake full cost accounting which includes negative externalities produced by coal. If this is done correctly, wind power could easily become cost competitive with coal power, possibly removing the need to subsidize the renewable industry altogether. Further investigation of the effects of externalities on LCOE's would therefore be an important factor for the growth of wind power and the renewable energy industry as a whole.

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