Cost Benefit Analysis of Lake Turkana Wind Project, Kenya

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ABSTRACT

Lake Turkana Wind Power is the largest single private investment in Kenya, the location for the wind farm is in an isolated rural area with powerful wind resource but suffers from no connectivity to the national grid. This study conducts a cost-benefit analysis which evaluates the financial and economic benefits of the Lake Turkana wind power plant. The results of the analysis show that the project had a return of €23.45 million in 2021 prices to the project owners.

The wind power plant compared to Rabai alternative gas turbine produced a low-cost energy providing an estimated cost of €0.10 per kwh while Rabai was estimated to produce energy at €0.15 per kwh. The cost savings to grid with the project amounts to €237 million. The effect of time overrun and cost of transmission delay were estimated to be €25 million and €83 million respectively. The net economic benefit of the wind project can be estimated to be €129 million.

Keywords: financial analysis, cost-benefit, wind power

ÖZ

Turkana Gölü Rüzgar Enerjisi, Kenya'daki en büyük özel yatırımdır, rüzgar çiftliğinin konumu, güçlü rüzgar kaynaklarına sahip izole bir kırsal alandadır, ancak ulusal şebekeye hiçbir bağlantısı yoktur. Bu çalışma, Turkana Gölü rüzgar santralinin finansal ve ekonomik faydalarını değerlendiren bir maliyet-fayda analizi yapmaktadır. Analiz sonuçları, projenin 2021 yılında proje sahiplerine 10.64 milyon Euro'luk getiri sağladığını gösteriyor.

Rabai alternatif gaz türbini ile karşılaştırıldığında rüzgar santrali, kwh başına 0,10 € tahmini maliyet sağlayan düşük maliyetli bir enerji üretirken, Rabai'nin kwh başına 0,15 € enerji ürettiği tahmin edilmektedir. Proje ile şebekeye sağlanan maliyet tasarrufu 353 milyon Euro tutarındadır. Zaman aşımının ve iletim gecikmesinin maliyetinin etkisinin sırasıyla 16 milyon € ve 161 milyon € olduğu tahmin edildi. Rüzgar projesinin net ekonomik faydasının 176 milyon € olacağı tahmin edilebilir.

Anahtar Kelimeler: finansal analiz, maliyet-fayda, rüzgar enerjisi

DEDICATION

(To my wife and family)

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Chapter 1

INTRODUCTION

Africa faces the challenge of creating more electricity to meet current and future demands, considering its lack of access to power for more than half a billion people across the continent. There is a clean and prosperous potential for many countries to do so. The continent has renewable sources of energy that are feasible alternatives to current energy shortages. Many countries have stepped up their efforts to encourage the use of renewables. At present, 164 nations have set renewable energy growth goals and policies (International Renewable Energy Agency (IRENA), 2016). Since wind power has earned so much support from the public, in addition to recognizing its overall effect, it is important to consider who gets profit and who bears the costs to help policymakers make informed and targeted decisions. One of the key aspects is quantitatively assessing the possible implications for local economies of wind energy production. There is argument that wind energy development supports not only local economies directly through production and construction of wind turbines, but provides intra-direct advantages through growing demand from industries, reinvestment, and direct and indirect beneficiaries of investments (Xia and Song, 2017). The effect of wind energy production is significant in local economies because wind resources in economically depressed regions like central and northwest China are frequently abundant (McComb et al., 2016). Swift growth is happening in the wind power industry. It is one of the world's fastest-growing energy sources, technology is rapidly evolving, and wind power supplies substantial power shares in large regions. The incorporation of wind power into the electricity system is now a challenge for maximizing resource usage and keeping track of the need for high wind energy installation to achieve the sustainability and protection of supply objectives. In recent years, grid integration concerns have been highlighted as penetration rate of wind power in many countries have increased to prevent wind power networks from being widened. Wind intermittence and grid stability are two of the main obstacles to wind power. The traditional transmission and distribution management is threatened by transforming the electricity sector, security of supply, and integrating new wind power technologies. The availability of transmission may be an obstacle to the production of wind power. New transmission lines can be difficult to build due to barriers in planning, property rights and costs. Convenient wind sites are also situated far from current transmissions (Georgilakis, 2006).

This analysis aims to conduct a cost-benefit analysis of the Lake Turkana Wind Power plant in Kenya using Integrated Investment Appraisal. The project's financial benefits are estimated both from a lender's point of view and the owner's perspective. Another estimation conducted is the economic benefits of the nation in which the wind project is located. The third reason is to calculate the cost of time overruns and quantify the delay in constructing the transmission line.

Chapter 2

LITERATURE REVIEW

2.1 Background

Developing countries are exploring different ways of increasing access to modern energy services from renewable energy sources. Kenya's energy use is dominated by biomass (68%), with petroleum products being followed by (21%) the remaining 1%, made of solar and other sources of power, and (9%) electricity (Institute of Economic Affairs (IEA), 2015). Wood fuel and charcoal are the major energy biomass sources and are used primarily in rural areas where 80% of the energy is estimated; Kenya's people use this kind of energy. On the other side, oil and electricity are imported into the two key domestic energy market components in Kenya and therefore directed to a broader energy market Expansion into urban areas that supply houses and industries alike. Electricity generation facilities back Kenya's growth goals as a priority. Better generation of electricity helps ensure a reliable and safe power supply – important for economic development and job creation. Increased renewable energy production also benefits from increased energy stability by reducing dependency on fossil fuel imports (2013 Government of Kenya, National Climate Change Action Plan). The total power generation installed in 2015 was 2,341 MW, consisting mainly of thermal power (35.6%), hydro (35.1%), and geothermal (27.0%), while most of the electricity produced was geothermal (47.0%) and hydropower (38.6%) (Erika 2018).

Kenya has one of Africa's highest wind output potentials. The wind is currently making a marginal contribution to the overall energy mix, but it is projected to increase dramatically in the coming years. Kenya's investment in renewables and wind was especially successful including the largest wind turbine wind farm in the mainland, the 310 MW lake Turkana Wind Power (LTWP). LTWP is also the country's largest private investment. Furthermore, several other large-scale wind energy projects are being built, among which the Lamu-based Baharini Electra Wind Farm project (90 MW), Isiolo (100 MW), Meru (60 MW), Ngong (51 MW). To accelerate energy expansion, Kenya has since the 1990s changed its legal and institutional structure (Kazimierczuk, 2019).

2.2 Energy Policy and Institutions

Kenya Vision 2030 (the Vision)

The country's economic strategy was introduced in 2008 to "transform Kenya into a newly industrialized, middle-income country providing a high quality of life to all its citizens by 2030 in a clean and secure environment". The Government of Kenya (GOK) aims through vision2030 to raise generation power in Kenya to 23,000 MW by 2030. Power is one of the Vision's eight primary sectors to boost its ambition (Power to Africa, 2017). To achieve the high growth rates of the 2030 vision, the Government stressed the importance of promoting involvement by the private sector, which led to establishing the following detailed public-private partnership investment system (PPPs). A basis for an improved institutional and regulatory structure for PPPs was provided by the First Medium Term (2008–2012), while the final policy formalized with implementing the PPP Act in 2013. The Energy Regulatory Commission claimed that electricity generation is liberalized in Kenya at the generation level, giving independent power producers (IPPs) a chance to compete in the field and State-owned

Kengen (ERC,2017). The proposed National Energy and Petroleum Policy and Energy Bill for 2015 proposed additional changes to the legal and institutional framework to promote a competitive wholesale market system.

Feed-In Tariff policy

Kenya's FiT policy takes a long-term view of renewable energy, in line with its aggressive power access goals, and mandates a 20-year minimum Power Purchase Agreement (PPA). Thirty days after receiving an invoice from KPLC and the standard PPA shall give the payments in a foreign currency for payment.

Kenya has a predominantly public sector-controlled energy sector, with national utilities partly privatized. State-owned utilities working under the Ministry of Energy (MoE) are primarily responsible for generating electricity and electricity distribution in Kenya. Kenya Power (KP), formerly Kenya Power and Lighting Company (KPLC), is a 51% government-owned monopoly responsible for distributing electricity in Kenya. Kenya Electricity Generation (KenGen) is a national electricity generation company, which accounts for the majority of installed electricity generation capacity and is owned by 70% of the state. KETRACO is a wholly-owned state-owned electricity transmission network corporation responsible for regional interconnections and transmission grid in Kenyan. The Energy Regulatory Commission (ERC) is a separate body responsible for energy sector supervision and planning Least Cost Power Development Plans (LCPDP). The Geothermal Development Company (GDC), a 100 per cent state-owned firm incorporated under the Company Act in 2008. The GDC falls within the MOE framework and is responsible for exploring geothermal fields, the exploration and production of drilling, the growth of steam fields, and the sale of steam to power plant operators.

Eberbacha, Hoffmanna, and Fortin (2019) examined the impact of implementing the recent European and National regulations and targets for wind power expansion on dynamic aspects such as land use, cost, wind turbine technology, and other factors using Poland as their case study. They employed a systematic approach comprised of two models; Spatial analysis of potentially available areas for onshore wind turbines, and spatial and temporal wind power dislocation under technological, economic, and wind power constraints. The rationale behind splitting into two models was that the spatial potential areas could only change if the spatial of regulatory constraints change. The study found that the distance regulations reduced Poland's wind onshore potential by up 63%, about 47GW to 82GW depending on the turbines' technology. It also showed that new turbines could be installed for €45-€50/MWh if good locations are selected. In conclusion, Poland's 2030 target of 10.3GW can be reached at LCOE below €60/MWh.

Pejman, Jenkins, and Frank (2020) evaluated the effects of wind energy displacement on other Ontario generation technologies. Using data from IESO's data directory (2015- 2018), an econometric study of the system's historic hourly demand and generation of electricity has been carried out to estimate the extent to which wind production affects the generation output of other types. Four estimation models were used to get the coefficients of available capacity of each generation technology. The financial and environmental benefits through fuel savings and revenues from exports were also estimated. Hydro displacement will lead to increased electricity generation when it comes to online or water spillage if the reservoirs are small, this electricity generated will also displace gas turbine generation. The nuclear generation is inflexible since it covers the base load of Ontario. The monetary value of carbon reduced by wind generation was estimated using the social cost of carbon. The study discovered that

53MWh and 23MWh of gas-fired generation and hydropower are displaced respectively for every 100MWh of wind electricity generated and about 19MWh is exported. The likelihood of wind generation occurring during the off-peak period coincides with nuclear power generation. It has made the Ontario government's effort to subsidize wind power generation an expensive endeavour costing annually 860 million USD.

Salci and Jenkins (2016) did an integrated investment appraisal to determine if the PPA negotiated could generate decent financial and economic benefits while appealing to lenders at the same time for a wind project in Santiago Island. Using the investment appraisal framework, the financial benefits were analyzed from two perspectives; the IPP and utility perspective. The IPP benefits are estimated from the amount of revenue generated from electricity production after subtracting the operating costs and taxes from their transactions. On the other hand, the public utility benefits from fuel savings due to thermal plant displacements due to wind power generation. The economic benefits are evaluated from taxes and distortions accounted by conversion factors, fuel savings, and social cost of carbon is omitted since the project collects carbon credits. The results of the study show that based on the actual PPA price, the NPV of the foreign IPP is EUR 18.4 million and the utility’s NPV became EUR -7.4 million and the net present value loss to the government in tax revenues is EUR 3.2 million summing up to a total loss of EUR 10.6 million was borne by the Cape Verde economy. As the wind farm saves power, the energy industry's net loss and the wind farm economy rise as fuel prices rise. For the economy, to break-even, the world oil prices have to be USD 69, which is above the current market price of oil. Since the exchange rate was fixed throughout the project life, the impact of appreciation or depreciation risk of EUR showed that the currency's devaluation improves the NPV of the Utility and economy and vice versa. They concluded that for wind projects to be economically viable, fuel prices have to be increasing, and wind expansion policies have to include ways to mitigate fuel prices.

Chapter 3

THE PROJECT

3.1 Location and Environment

Lake Turkana Wind Project (LTWP) is located in Laisamis constituency, Marsabit County, North-west Kenya. The county falls within regions of arid and semi-arid land (ASAL) bordering the north of Ethiopia, the west of Turkana County, the south of Samburu County, and Isiolo Wajir Counties. The county has a total population of about 459,785 people. It occupies a total area of 66,923 square kilometers, characterized by vast plains bordered by hills and mountain ranges, according to the 2019 Housing and Population Census.

The region has unique geographical conditions. Wind flows are predictable, strong, between Lake Turkana generate regular changes in temperature (at fairly steady temperature) and hinterland of the desert (with rapid variations in temperature). The 40,000ha project site is at 400 meters elevation between Lake Turkana's southeastern tip and the Mt. Kulal footpaths, witnessing heavy winds. The average wind speed at the site exceeds 11m/s. Compared to the rest of Kenya, the wind in the planned wind farm region is intense. The winds come from a stream called the “Turkana Channel low-level jet”.

3.2 Components of the Project

The project involves constructing a wind farm and a subsidiary project involving the reconstruction of about 200 km of the current rural roads. The project financiers are an

IFU, Finnfund, Vestas, Norfund,KP&P Africa B.V., Aldwych International, sandpiper limited, and a loaning consortium. Vestas plays a twin role as an initial shareholder within the LTWP syndicate and a key provider of turbines to the LTWP project. Other contractors engaged in the LTWP project are Siemens, Civicon, Southern Engineering Company Limited (SECO), and Rongxin Power Engineering RXPE (Developers).

3.2.1 Wind Farm

The wind farm proposed comprising of 44m hub height 365 V52 Turbines. The electricity generated by the overhead power line (33kV) electrical collector system and the step-up transformers involved (33/400kV), sitting in the switchgear will be evacuated through the turbines. Power will be evacuated from the switchgear via the busbar and the circuit breaker device related to the suggested 400kV transmission line. With an installed capacity of 310MW, each turbine has a capacity of 850KW. The Government of Kenya has leased a concession area of 150,000 acres for a 99-year term. The wind farm's footprint will be roughly 162 km^2 (40,000 acres), with the rest of the area serving as a buffer for the wind farm. It takes a total of 32 months to build the wind farm. The planned wind turbines are projected to last for 25 years. The power station also consists of a STATCOM and a control (or SCADA) system that regulates the voltage within safe operating limits. From Suswa, the power is routed to the Nairobi Metropolitan Ring, which consists of six sub-stations, namely Suswa, Nairobi North, Dandora, Embakas, Athi River, and Isinya. Through the Kenya Power and Lighting Company (KPLC), these sub-stations' power supply goes to consumers, including households and businesses. According to a Power Purchase Agreement signed by LTWP and KPLC, the company will purchase the project's power at a fixed price for 20 years.

The power produced will move through a planned 400kV transmission system onto the new Suswa switchgear at approximately 428 km. The transmission line's construction is the Kenyan Government's responsibility through their Electricity Transmission Company (KETRACO). The transmission line is set up by KETRACO and an agreement with Kenya power is arranged with regards to tolling of power. This transmission line installation is taken into consideration as an 'associated facility,' i.e., the wind farm will require the installation of a national grid electric transmission line from the wind turbine. The transmission line development is an independent project from the LTWP project.

3.2.2 Rehabilitation of Road

The wind farm proposed is situated about 1,200 km from the port of Mombasa from where all materials will be transferred to the farm via land. There is already a large portion of this road; but, approximately 200kms of existing rural road goes from Laisamis to Illaut to Kargi, Kargi to the wind farm Loyangalani (C77) calls for restorations, including enhancing, realignment, levelling and grading, culvert manufacture and maintenance. The street is 6m wide with a reserve on either side of the street of 5m. After discussions with stakeholders and concerns about the impact of bad transports, route diversion was strengthened to avoid existing Ngurunit, South Horr, and Kurungu settlements. It is expected that the 200 km road will take approximately 15 months to construct.

3.2.3 Environmental and Social Management Plan

The ESMP was established as an essential environmental protection mechanism in the project sector, including a monitoring plan. This Plan aims to protect the local communities; the project operators; and the natural environment. Furthermore, the existence and activities of the completed wind farm will show improvements and patterns. The following characteristics are the monitoring program's key features: Compilation and analysis of relevant environmental information; periodic report planning including the Project Lender annual report on environmental and social results, and liaison with related authorities (e.g. NEMA).

3.2.4 Resettlement Action Plan (RAP)

LTWP's primary concern during construction was for the health and safety of the community of Sirima, a nomadic village within the concessional area of the wind farm. The village is situated along the third class C77, which runs some 40 kilometres to the North West and South Horr to Loiyangalani District, about 50 kilometres south-east. To avoid accidents and to prevent needless unfortunate incidents for the community in Sirima, it is important to move the settlement temporarily to an area outside of the C77 to a building site not part of the project. The Resettlement Policy Framework (RPF), along with the environmental impact assessment (ESIAs), has since been submitted for both wind farming and road reconstruction to Public disclosure information channels of the African Development Bank (AfDB) and the World Bank (WB).

3.2.5 Winds of Change

In 2015, LTWP founded the Winds of Change Foundation (WoC) for Corporate Social Responsibility (CSR). The foundation was aimed at catalyzing positive, sustainable development in the wind farm areas. Throughout the wind farm's 20-year operation, LTWP has committed funds from its operational profits to WoC. Before 2019, WoC was funded by lenders, partners, and others like Siemens, through the LTWP project. Even following the wind farm's introduction and LTWP's engagement, this has continued. WoC reinscribed as a non-governmental organization in 2019 (NGO). It collaborates with multiple players, among which County Government, non-governmental organizations such as Mission to Heal (M2H) and Terre des Hommes, Community-based organization, and government departments, for implementing projects in community development among target communities. WoC wants to recruit local contractors to carry out community-based projects, creating new jobs for the communities.

3.3 Contractors

In December 2014 Vestas was offered to supply and build 365 turbines for Lake Turkana. The contract scope additionally consists of 15-year active output management (AOM) service settlement. Siemens was contracted to supply and install the high voltage gadgets for Lake Turkana wind farm including transformers. DAHER was subcontracted by Siemens for electrical system transportation and logistics. Worley Parsons was signed for the project control, engineering assessment, and construction control project in November 2014. DNV GL supplied advisory offerings for the Loiyangalani-Suswa transmission line. COWI dedicated itself to providing distinctive engineering services to wind turbines and foundations, design review, acceptance tests, in addition to production supervision for the scheme. Mott MacDonald offered technical support for the cause to creditors. Dynamic Reactive Compensation systems for the wind farm were completed by Rongxin Power Engineering in January 2012. SECO and Civicon have been involved in the site development work of the Lake Turkana wind farm.

3.4 Project Loan

Lake Turkana's wind power project has been funded by 70% of senior debt and 30% equity. Wind farm lending institution includes African Development Bank (AFDB), European Investment Bank (EIB), the US Overseas Private Investment Corporation (OPIC), Proparco, the Standard Bank of South Africa, East African Development Bank, PTA Bank, EKF, Triodos, and DEG.

3.5 Project Objectives

According to PPA, this project aims to supply the national grid with 310MW of reliable, low-cost wind energy, which is around 20% of the electricity generating installed capacity purchased by the KPLC at a fixed price. With the introduction of 310MW in the national grid, power failures will be reduced, particularly in dry seasons. The strong dependence of the country on power generation from the oil and diesel generators will be reduced. The project will generate significant positive consequences with full power production (operation of 365 wind turbines, each with an ability of 850 kW), especially when hydropower is lowest in its production during dry years. The project is intended to reduce emissions of greenhouse gases. Clean Development Mechanism (CDM)113 was approved for the LTWP by the UN Climate Fund Secretariat in exchange for its efforts to lower emissions of carbon in Kenya. The project will average annual emission emissions of carbon dioxide (CO_2) equal to approximately 740,000 tons (tCO_2eq) of CO_2 equivalent. The annual sales of up to EUR 6 million are expected for carbon credits. LTWP has agreed to return a portion of the revenues produced from carbon credit to the Government of Kenya, which, in turn, is expected to give a certain percentage to Wind of Change (WOC). These innovations would eventually contribute to greater social welfare.

In stimulating economic growth in Kenya, this project will play an important role. The electricity input would substantially contribute to the Kenya Rural Electrification Programme, which is likely to spin off Kenya's rural economy. The project also has the potential for energy exports to neighbouring states such as Uganda, Tanzania, and South Sudan. The energy situation in Kenya today is unsatisfactory, as shown by the frequently unplanned power failures, a major event that delays the country's economic growth. The road conditions of the project area are currently deplorable. The project will develop roads from Marsabit City via Kargi to Loiyangalani to facilitate smooth transportation. The rehabilitated road would enhance connectivity and encourage economic activities in the project area, including animal traffic. Loiyangalani fisheries would be a major beneficiary of an enhanced road system. This sector has immense potential that was never used because of poor road conditions between the lake and potential markets. Fishers cannot sell fresh fish because of the bad road system.

3.6 Mechanical Completion

Mechanical completion of any project can be considered a phase at which equipment construction is physically complete, tests have been done, and production can be managed at a certain capacity for a certain period. If any party did not supply a wind farm, or a Transmission Interconnector (TI), respectively on time the PPA included contractual consequences for both LTWP and KETRACO. On 27 January 2017 LTWP completed the First Commercial Operations (119 WTG), and on 29 August 2017, all 365 WTGs were extended. In September 2018, the TI was finally shipped. Under PPA, it was "mechanically complete" – that is, as long as LTWP had at least 50 MW (59 WTGs). If the transmission interconnection (TI) process had happened, it might have generated electricity. LTWP is entitled to be paid TI delays based on this contractual arrangement.

Chapter 4

METHODOLOGY AND DATA

The data used in the analysis are majorly from documents of African Development Bank (AFDB), Aldwych International, and Kenya vision 2030 Least Cost Development Plan documents made publicly available.

4.1 Financial Analysis

The financial analysis is aimed at assessing whether a project is financially feasible. It typically provides the basis on which other analyzes are created. It covers the number of expenses and revenues expected to be generated by the project. It also deals with project funding and highlights its ability to fund its activities and maintenance costs.

4.1.1 Variables and Assumptions

In this part, the main variables and Assumptions used for the project's financial analysis are specified.

4.1.2 Project Timing

The project was assumed to have four years rehabilitating the site, constructing and installing the wind turbines and sub-station (2014-2017). The operation is supposed to commence in 2018, where the wind plant generates power to be distributed to consumers. During these 20 years (2018-2037), the project will receive revenues and maintain the power plant, ensuring it is in good condition. 2038 is reserved as the liquidation and decommissioning period in which the plant is handed over to Kenya Electricity Generation (KENGEN).

4.1.3 Investment Costs and Project Financing

A total investment cost of €622 million was allocated, with a project loan of €435 million was agreed between the Lake Turkana wind project and a group of lenders.

Table 1:Capital expenditure

Item	Million €
Machinery Cost incl. Installation	362
Electrical Infrastructure incl. Installation	68
IDC & Contingency	70
Site Development	59
Construction Cost	12
Debt Service Reserve Account	36
Financing Cost	15
Total	622

The Drummond (2012) mathematical model is used to distribute investment costs during the project's construction period. The assumed financing structure in the model is a senior debt of 70%, and equity would be 30%. The following are the terms and conditions assumed for the development of the debt repayment profile:

- The loan grace period will be over 4 years, which is equivalent to the construction period.
- It is presumed that the loan will be repaid for 12 years for principal and interest. Interest payments would attract a subsidized interest rate equal to 4.5% annually. Interest during construction would be capitalized.

4.1.4 Project Operating and Maintenance Costs

Annual operating expenses (AOE) usually includes: land lease costs (LLC), salaries and supplies for operations and maintenance (O&M), and levellized replacement costs (LRC). Fixed O&M, comprising the known operating cost, (e.g., maintenance schedule, rent, leasing, tax, utilities, or insurance) and usually not changing depending on how much electricity is generated. Variable O&M, including unplanned repairs, and other project-life costs, according to the amount of electricity generated. The AOE can be translated to a single term for convenience as €45/kW/yr (Cost of wind energy review, 2015). This is broken down into:

Table 2: Operating expenditure

Power Consumption required (Proportion of Capacity)	8.3%
Overhead Cost (Proportion of OpEx)	17%
Insurance Cost (Proportion of OpEx)	13%
Services & Spare parts (Proportion of OpEx)	26%

The project employed around 2500 employees during construction and 485 during it operation. The mean estimate of labour compensation for these workers during operation is €737 per month inclusive of bonuses and other benefits. Among the employees of which 96% are marsabit county indigenes, 3% from the rest of the country and 1% are expatriates.

4.1.4.1 Working Capital

The working capital of LTWP is assumed to be 8% of sales revenue as account receivables while account payables are 8% of operating cost excluding labour.

4.1.4.2 Inflation and Exchange Rate

Our analysis's domestic inflation rate is 7% per annum and the foreign inflation rate (Europe) of 2% per annum. An exchange rate of 107 Ksh/Eur was assumed.

4.1.4.3 Discount Rate

The discount rate reflects the cost of opportunity of funds invested in the project. The discount rate in the financial analysis depends on the analysis viewpoint (desired return on equity or a weighted average cost of capital). The opportunity cost of capital for this project is assumed to be 10%. The relevant discount rate is the nation's economic opportunity cost of resources when an economic analysis of a project is performed.

4.1.5 Taxation

LTWP has tax exemption on the equipment and machinery purchased, i.e. capital cost for the power plant but will subsequently be taxed on their revenues and operating costs.

4.1.6 Decommissioning cost

Significantly new to the wind sector is the decommissioning of wind, as the vast majority of wind turbines in the USA are not retired. To this end, interested parties' data and industry experience are inadequate to easily identify what cost decommissioning might have on the community following the project's useful life (Energy ventures analysis, 2019). The decommissioning cost assumed for this analysis is 121700 Euros per wind turbine.

4.1.7 Electricity Tariff

A power purchase agreement (PPA) was made by LTWP and Kenya Power Lighting Company (KPLC) for 20 years to come. For the first six years of the PPA, the low-cost initial rate is EUR 0.0853 per kWh, further downward modified for the remaining 14 years to EUR 0.0752 per kWh. This is considerably less than other energy prices. The escalation component of this price is 14% linked to Euro inflation. The average capacity factor for the wind farm was calculated to be 57% for the year 2019 which was used for this assessment.

4.1.8 Financial Cashflow

The financial Net present value (FNPV) and IRR are the criteria used to test the project's financial feasibility. Mathematically, the FNPV is denoted by equation 1 below:

$$FNPV_{t=0} = \sum_{t=0}^{n} \frac{Inf_t - Outf_t}{\prod_t (1+r_t)} \quad (1)$$

Where the financial inflows are referred to Inf_t from operating and the residual value of wind turbines in period *t*, $Outf_t$ connotes the accumulated cost of producing electricity available for sale, *n* connotes the defined period which the study was performed, *t* indicates each period, and *r* shows opportunity cost of capital.

The cashflow use to express the FNPV is a function of inflows and outflows of the project. The financial inflows towards the project can be expressed as in equation 2:

$$Inf_t = Rev_t^{eng} + Rev_t^{CER} + RV_{t=n} \quad (2)$$

Rev_t^{eng} refers to sold energy revenue in period *t*. Rev_t^{CER} allude to the income from carbon emission reduction in period *t*, and $RV_{t=n}$ expresses the residual value of the project in the period *n* to connote the final period of the appraisal. The energy sales revenue is mathematically measured in a period *t* by equation 3 below:

$$Rev_t^{eng} = (Ent \times CPTY \times HR \times (1 - PSR) \quad (3)$$

$CPTY$ expresses the plant's gross capacity in Megawatt, PSR asserts to the power usage of the plant, Ent is the electricity price including tax per MWh on selling of electricity. The time the plant is running each year is indicated as *HR*. The power service rate refers to the energy required by the power plant to generate electricity. The revenue generated from carbon emission reduction in a year *t* is expressed as equation 4:

$$Rev_t^{Cer} = Cer \times Ces_t \quad (4)$$

Cer denotes carbon emission reductions or carbon credits price, Ces_t refers to the project's annual carbon emission savings. The financial outflows of the project are expressed as:

$$Outf = Capex + O\&M + Tax \quad (5)$$

Where $Capex$ connotes the capital spending required to be invested during construction, and O&M represents the total operating and maintenance expenditure essential to sustain the power plant running each period. The O&M cost comprises overhead costs, insurance, labour compensation, cost of feed-in energy, cost of service, and spare parts.

$$O\&M_t = (EnR \times Mf) + (W^{no} \times C^{avg}) + InsC + Ovh + Csp \quad (6)$$

Where EnR is the energy required by the power plant for operation, Mf is the marginal feed-in tariff for Kenya, W^{no} is the population of workers and C^{avg} is the compensation of workers including every benefit like pension, and bonuses, $InsC$ refers to the insurance cost, Ovh is the overhead costs, Csp refers to the cost of service and spare parts.

Bankers perspective

The evaluation criteria used from the lender's point of view is the debt service ratio (DSCR) and loan life coverage ratios (LLCR). Debt Service Coverage Ratio is measured to see if the generated cash flow for a given year can pay the same year's debt service. It is calculated as in equation:

$$DSCR_t = \frac{CFADS_t}{P_t + I_t} \quad (7)$$

$CFADS_t$ is the available cash flow for debt servicing in period *t*, P_t is the principal payment for period *t*, I_t is the interest paid in period *t*. Cash flow available for debt service can easily vary from net cash flow based on some term agreements like funding the debt service account.

The loan life coverage ratio shows the ratio of the cash flow for debt service during loan repayment years in present value and the debt balance's present value. LLCR shows the project's ability to pay its debt and is mostly needed when the DSCR lacks some years (bridge financing). It is calculated as:

$$LLCR_t = \frac{PV(CFADS_t{:}CFADS_m)}{PV(Debt\ service_t{:}Debt\ service_m)} \quad (8)$$

Where $PV(CFADS_t: CFADS_m)$ is the present value of cash flow available for debt service for the loan years and $PV(CFADS_t: CFADS_m)$ is the present value of the interest payment plus principal for the duration of the loan.

4.2 Economic Analysis

The economic analysis of a project focuses on the social effects of the project and whether it improves the whole society's economic well-being. The discrepancies between the analysis of a private venture conducted by owners and the differences in conventional ventures in the public sector are generally concentrated in evaluating benefits. The majority of the project costs are, in reality, cash, much like those of a business company. The project's economic viability is focused on the incremental economic benefits and costs created over the entire project life. Electricity projects seem to be in a different group because such projects' true benefits are hardly ever calculated. The least-cost principle is used in his analysis to calculate the benefits of the project. This concept explains that one should not assign a benefit value to a project that exceeds the lowest alternative cost that one should incur by offering an equivalent benefit source in another way (Harberger et al.,2019). In reality, the traditional way of doing things is often simply the next best option. The projects that are evaluated then try to find innovative or different ways to do better things than the traditional alternative. The alternative cost that would have been incurred rather than the estimated project would be the evaluated project's gain if the evaluated project were not carried out. For electricity projects, there are 2 different ways to do this; one approach is to evaluate all feasible options and compare their levellized costs. The other is to create a standard solution for comparison purposes. For this analysis Wind Project, the Rabai power plant, a combined cycle gas turbine in Kenya, was used as the standard alternative for comparison. Although Rabai is a 90mw capacity power plant, its marginal cost structure was estimated to generate the same amount of energy as the Lake Turkana wind project. Basically, the plant is estimated to have utilization hours of 1449 hours—the wind plant at an average capacity factor of 57%. The wind energy project's economic benefit is derived from calculating the cost of using alternative thermal plants to generate the same volume with an equivalent load factor. Based on actual HFO price data, which corresponds to each of the wind power projects' years of service up to 2020, the benefits obtained from the wind power plant measured by costs saved by not using the alternative way power is generated—are calculated. The rates are expected to be set at US$454 per tonne and €0.35 per litre from 2020 to the end of the project lifetime (20 years).

4.2.1 Economic Parameters and Assumptions

The Foreign Exchange Premium and Non-tradable outlay are measure at 8.2% and 0.84% respectively (Salci and Jenkins 2015). For primary, intermediate, and finished products, import tariffs of 0%, 10%, and 25% are applicable. The value-added tax for Kenya is 16%, and the composite effective tax rate is 23.4%. The cost of domestic freight and port handling charges are assumed to be 5% of the CIF price.

4.2.2 Conversion Factors

Conversion factors to transform from financial analysis to economic analysis are essential in assisting the transition. The economic value to financial value ratio is typically a conversion factor. In the financial analysis, every line is multiplied by the related conversion factor to switch from financial analysis to economic analysis. The financial benefit of tradable goods involves distortions like import duty and VAT prices but does not take the premium from foreign exchange (FEP). However, the cost of these things is measured to eliminate the numerous distortions and include the FEP. If a conversion factor of less than 1 is reached, these products' prices are higher than their economic values. CSCF is estimated as:

$$CSCF = \frac{Economic\ value}{Financial\ value} \tag{9}$$

Table 3: Shows a summary of the conversion factors

Items	Conversion Factors
CapEx	1.04
Insurance	1.08
Cost of services and Spare parts	1.01
Cost of feed-in energy	0.83
Labor compensation	0.97
Fuel	0.77
Electricity	0.83
Machinery and electrical infrastructure	1.07
Transportation	0.81
Overhead cost	0.96
Change in account payable	1.0

The cost of construction consists of site development and the machinery and materials used for construction. Total distortions equivalent to 4% of the financial cost were found. Therefore, the wind farm and its remaining value are comparable to the financial value of 4 per cent inclusive of FEP. Many of the distortions in the financial costs of Import tariffs, VAT, and income taxes are in the wind farm construction. For the tradable components, the power plant has exemptions for most of these distortions. They are majorly materials and equipment, the non-tradable components distortions are removed, and Non-Tradable outlay is added, making the aggregate distortions result in a conversion factor of 1.04.

Operating costs consist of overhead costs, insurance, labour compensation, and feed-in energy costs while maintenance comprises labour and cost of services and spare parts. Income taxes and VAT are the key distortions in the financial value of the cost of running and maintaining the wind plant. The distortion in the insurance market is due to the foreign exchange premium as the payments are made in foreign currency overseas. Consequently, the conversion factor for insurance is equal to 1 plus the FEP. Labour cost consists of skilled, semi-skilled, and unskilled labour, with their distortions being primarily income taxes and VAT. Removing these distortions equivalent to 3% and finding their weighted conversion factor to be equivalent of 0.97. Feed-in energy is power from the grid with a distortion of 17%, and the conversion factor is equal to 0.83. The cost of services consists of semi-skilled labour and equipment replacement with their weighted conversion factor to be 1.01 using weights of 50% each. The accounts payable consist of the outstanding operating and maintenance costs; the average of the CSCFs for operating and maintenance expenses for accounts payable was measured to equivalent to 1.

4.2.3 Economic Resource Flow

The economic analysis has been developed for comparison of the levellized cost of energy for both plants. The levellized cost is calculated as in the equation below:

$$LC_j = \frac{\sum_{t=0}^{n} \frac{C_{jt}}{\prod_t (1+EOCK_t)}}{\sum_{t=0}^{n} \frac{Cap_{jt} \times HR_{jt} \times (1-PSR_{jt})}{\prod_t (1+EOCK_t)}} \quad (10)$$

C_{jt} reflects the economic value of investment expenditure and variable costs of plant *j* in period *t,* where 11% represents $EOCK_t$ economic discount rate throughout period *t*, Cap_{jt} alludes to the maximum ability of plant *j* supplied to the power grid in period *t,* HR_{jt} indicates number of hours per year for the time *t* for which plant j was used, and PSR_{jt} signifies the plant service usage rate, which defines the total energy ratio provided by a plant which it is using itself rather than transferring to a grid. The equation's numerator expresses the present value of cost valuation, while the denominator calculates the present value of energy generated to the electrical grid. As shown in equation 11 below, the economic valuation of a plant *j* cost consists of two parts.

$$C_{ht} = Capex_{jt}^{e} + Opex_{t}^{e} \tag{11}$$

$Capex_{jt}^{e}$ expresses plant *j* economic evaluation of capital cost and $Opex_{jt}^{e}$ indicates operating expense for plant *j*. $Opex_{jt}^{e}$ is mathematically computed by equation 12 below

$$Opex_{jt}^{e} = F_{O\&M} \times CPTY_{jt} \times HR_{jt} + V_{O\&M} \times CPTY_{jt} \times HR_{jt} + CE \times C0_{jt} \times CPTY_{jt} \times HR_{jt} + FR_{j} \times FP_{jt} \times HR_{jt} \times CPTY_{jt} \tag{12}$$

$F_{O\&M}$ represents unit cost of electricity for the static component of running and maintenance expense for plant *j*, $V_{O\&M}$ represents the unit responsive component of the running and maintenance expense for plant *j*., CE alludes to the financial calculation of the environmental cost of carbon, $C0_{jt}$ refers to the fuel carbon element in the power plant *j*, FR_{jt} refers to the plant's fuel requirement *j*, and FP_{ht} means the price of fuel used in plant *j* in period *t*.

Chapter 5

RESULTS

5.1 Financial Impact

The project owner's net cash flow is known as the equity return based on the amount invested. Under the terms defined in the loan agreement, this assessment assumes that a loan worth 70 per cent of investment cost was awarded. This means that cash spending was regarded as the consequences of funding such as loan disbursement; interest charged and principal refund. The NPV from the owners' point of view shows how much the owner will reap more than the cost of funding opportunities represented by the existing discount rate for his investment. Capital investment started in 2014, and construction finished in the middle of 2017. However, the delay in constructing the transmission line could only make operation begin in September 2018. According to above equation 5, the total outflow was determined. The operation was studied for 20 years. In 2038, the year the project ends, all properties are liquidated. The inflow shown in 2038 is essentially the salvage value of the current asset's disposal following the accounting of the loss of economic depreciation. The wind project allowed the owner of the project to invest €186 million in equity, in addition to the supposed 70 per cent contribution from the funding partner. The net cash flow from the point of view of the project owner and the total expenditure perspective, applies to the disparity between overall financial inflows and project outflows is illustrated herein.

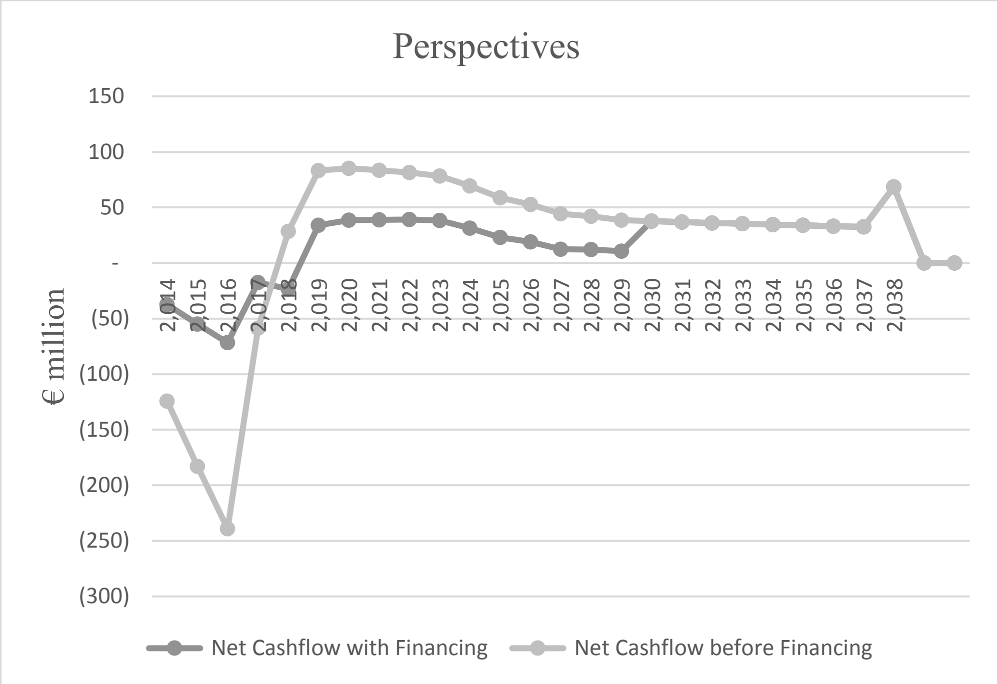

Figure 1:Net Cashflow from both the owner and overall investment viewpoint

There are the cumulative effects of debts and interest and principal repayments in the difference between net cash flow before financing and net cash flow post financing. The view of the banker is the net cash balance before financing, also called the total investment view. To assess the projects' financial viability, loan requirements, and the probability of loan and interest repayments, the banker considers any project's financial gain or expense. Conversely, after financing net cash flow is the expense of the project that the owner checks.

Table 4: Financial NPV of the lake Turkana wind power from the viewpoint of the owner (2021 values)

Criterion	**Value**	***Unit***
Discount rate	10.00%	*%*
NPV	**23.45**	*million EUR*
IRR	**11.27%**	*%*

The NPV shows how much the project would get its investors more than their financial opportunity cost. The project's financing NPV is €23.45 million, as demonstrated in table 4 above. This translates to €23.45 million in current values for the project owner, who is LTWP, more than if the project's capital had been invested in an alternative project that produced a 10 per cent return over the same period. If used as the discount rate, the IRR is the return rate that would make the project's financial NPV zero. Table 4 above indicates that the return rate of the project is 11.27%. As the IRR is greater than the rate of financial discount calculated, it indicates the project produces more returns for the same duration than an alternative project that yields a 10% return.

From a banker's viewpoint, the immediate interest is not the project's net return to the owner. The bank's most direct interest is the project's ability to repay the requested loan. This appraisal brings into question the overall financial value of the project itself. The banking authority assesses the project without taking into consideration the financial consequences of the loan. To understand how the project is financially sound. This viewpoint considers both the overall return on projects and the project's capacity to repay the negotiated loan by delivering sufficient cash flow. This also means that the assets' historical costs are generally not taken into account, as the bankers mainly tend to claim the project's net cash flows first. Unlike the owner's point of view, where the net cash flow is used to measure the investment, the banking firm would use the net cash flow to determine the total project until it is financed. The Debt Service Coverage Ratio (DSCR) is a key tool that helps you understand whether a project will produce adequate cash flow for the debt payment due in the same operation year. It helps the banker to find out a year which may be a difficult time covering its debts for the project. The minimum acceptable DSCR varies between banks and projects. The risk perceived by the lenders is typically inversely related to DSCR. Security schemes may usually be taken to reduce the likelihood of a project resulting in less reasonable minimum DSCR ratios. The wind farm project had a minimum DSCR of 1.3. The project was able to attain a DSCR above 1.3 for most of the loan repayment period except for the first year of operation, producing a DSCR of 0.57 way below the acceptable figure. The net cash flow for that period was low due to the project's inability to generate enough revenue due to transmission delay. This is the most difficult period to cover its debt payment. However, the project had a partial risk guarantee of €20 million for the transmission delay covered by the African development bank. The analysis assumes this nonexistent and will use the Loan Life Coverage Ratio to measure the project's ability. The project can generate sufficient funds to service its debts with an increasing LLCR, and the project has a solid security arrangement.

5.2 Economic Impact

The economic impact explains the cheapest electricity generation system from a societal perspective. It compares the Turkana Wind Lake with the gas turbine alternative Rabai. This study assesses the options' economic effect from an optimization perspective in which system planners design to increase the wind turbine's ability to generate a low-cost supply. This study is intended to examine the more economical way to deliver the base power produced. It seeks to understand the best way to add energy to the grid between the two choices.

As an alternative facility, a 300MW gas turbine was used for the levellized alternative energy costs compared to the wind generation. The study of the Rabai gas turbine plant was based on the unit cost reported by the Least cost power development plan (LCPDP) (LCPDP 2017-2037) and a study published by (Saule and Jenkins, 2016).

This comparative assessment was also taken into account the social cost of carbon produced by the gas turbine. The results of the analysis are shown in figure 6 below.

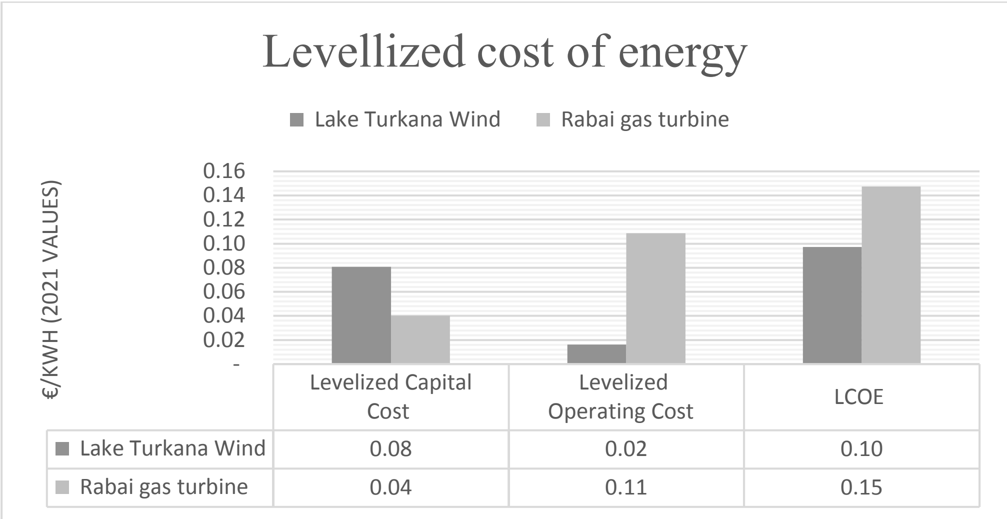

Figure 2: Levellized cost of energy

The findings have shown that the wind turbine is more economical than the Rabai gas turbine. Both capital, fuel, and carbon cost are included in the calculation. The wind turbine at Lake Turkana costs €0.10 per kWh for marginally less, while the Rabai gas turbine costs €0.15 per kWh. A levellized capital cost of €0.08 per kWh was expected for the wind power station. This is twice the capital cost of the gas turbine facility per kWh. The gas turbine used by Rabai, by comparison, required five times the wind turbine operational expense. Equation 12 includes this operational expense, including charges for fuel, O&M, and environmental costs of CO_2. The fuel costs are a big part of the operating expense, rendering it vulnerable to oil-and-gas prices. The levelized cost of transmitting this energy was estimated to be €0.02 per kWh in addition to the cost of generation.

Table 5: Total cost savings and transmission cost

	Cost Savings		
CAPITAL COST SAVINGS		NPV	Unit
	Annual Capital Cost of Thermal Alternative	272	million EUR
	Economic Valuation of Capital Cost of Wind Power Plant	-549	million EUR
	Capital cost savings to grid	(276)	million EUR
OPERATING COST SAVINGS TO GRID			
	Operating Cost of Thermal Alternative	765	million EUR
	Economic Valuation of Operating Cost of Wind Turbine	-112	million EUR
	Transmission Cost	-140	million EUR
	Operating cost savings to grid	513	million EUR
	Aggregate cost savings	**237**	**million EUR**

The gas turbine will have a less investment cost, as stated in the above table 5. The gas turbine would have saved €276 million in capital costs relative to the wind turbine in terms of present value. Considering the operating costs would save €513 million in the present net value over 20 operating years, in contrast with the gas turbine, lower operating costs for the wind turbine.

5.2.1 Cost of Time Overrun

Initially, the project was supposed to start operations by late 2013. However, the project was unable to reach financial close due to delays in environmental impact studies and the world bank's withdrawal. The world bank believed that Kenya does not have enough demand to match Lake Turkana wind power production and raised doubts about completing the transmission line at the agreed period. This delay has both merits and demerits. These advantages derive from the present value (PV) of project managers' costs, which can be saved by postponing actual capital spending since real project charges are discounted for a longer duration. The costs come from electricity generation by alternate means for the period of delay and the marginal cost of the alternate means of producing power (MRC) (Saule and Jenkins, 2016). The difference, which is the cost of time overrun, is shown in table 6 below:

Table 6: Cost of time overrun

Cost of Time Overrun	**NPV**	***Unit***
Net Impact of Capital Expenditures	223	*million EUR*
Forgone Savings in Running Cost due to Postponement	248	*million EUR*
Net Impact of Time Overrun	(25)	*million EUR*

The net impact of time overrun in figure 8 shows that Kenya is incurring €25 million due to the wind project's delay. The net impact of capital expenditure shows the benefit acquired due to postponement of cash outlay. The forgone savings in running cost due to postponement are the cost of running the alternative plant for that period the wind plant was supposed to be in operation.

5.2.2 Cost of Transmission Delay

As the building of power grid transmission lines has been obstructed, the commissioning in Kenya was postponed until late 2018. During the project turbines' idleness, LTWP, in its Power Purchase Agreement (PPA), did not obtain the negotiated amount of $75.20/MWh. The Kenya Government decided to pay the Lake Turkana wind power in September 2017 after negotiations in monthly instalments. This was financed by raising energy bills for consumers.

Table 7: Cost of transmission delay

Cost of transmission delay		**NPV**	***Unit***
	Additional Cost of Electricity Generation from Alternative Means for The Duration of The Delay	83	*million EUR*
	NPV of Cost of Transmission Delay	83	*million EUR*

The cost of transmission delay as shown in the above table 7 is the additional cost of electricity from a gas-fired turbine utilized to produce electricity that the project would have been generating for that period.

Chapter 6

SUMMARY

Although the project went through many challenges before it could commence, the financial feasibility for the Lake Turkana wind power project owners was assessed, and this demonstrated the project's ability to generate adequate cash flow to run and sustain itself. The results of the study based on the NPV criterion shows that with a FNPV of €23.45 million the project also produces enough cash flow to finance it loan.

The impact of time overrun are calculated as the cost of electricity production from alternative sources of energy during the delay in constructing the wind power plant and the cost of this time delay was estimated as €25 million. The effect of transmission delay was also evaluated and it amounted to €83 million in cost to the society.

The project demonstrated that the wind power plant, despite the high capital cost, was financially viable and the better alternative. The wind project emerged as the cheaper source of energy. The project remained economically viable despite the failures of the government to finish constructing the transmission line at the agreed time.

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