UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUTE OF SCIENCE AND TECHNOLOGY

FEASIBILITY ASSESSMENT AND GHG ANALYSIS FOR A 75MW WIND ENERGY PROJECT IN IRAQ

Master Thesis

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Institute of Science and Technology

Mechanical and Aeronautical Engineering Department

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Luay Faisal Karkez Al-Mamory

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Wind energy is renewable and environmentally friendly, and it can be connected to various users. A precise knowledge of the wind energy regime is a pre-requisite for the efficient planning and implementation of any wind energy project.

The relationship between energy consumption and environmental pollution has become clear from the negative results, so it has become necessary to convert from fuel consumption to alternative and innovative sources of energy, such as wind energy, solar energy, ebb and flow energy, and active mass energy. One of the least costly and most suitable alternative resources is wind energy. Iraqi urban communities which have experienced a deficiency in electrical power have the winds around them that can be used to generate electrical power. Our examination embraces a technique that suits the subject by uncovering the significance of the power of wind. We examine how it can be used, its components, by means of technical analysis (Wind speed, Annual electricity production and capacity factor), greenhouse gases analysis and financial analyses [Simple Payback(SPB), Net Present Value(NPV) and Annual Life Cycle Saving(ALCS)] for all data in this research. We study the potential of wind energy for Iraq by selecting the best four sites, namely Al-Nasiriyah, Al-Amarah, Mandali, and Samarra, which are distributed in all areas of Iraq.

Keywords: Wind energy project, wind data assessment, Technical analysis, Greenhouse gases emissions analysis, Cost and financial analyses.

ÖZET

FİZİLİBİTE DEĞERLENDİRMESİ VE IRAK'TA 75MW RÜZGAR ENERJİSİ PROJESİ GHG ANALİZİ

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Rüzgar enerjisi yenilenebilir ve çevre dostudur.Birçok çeşitli kullanıcılar tarafından kullanılabilmektedir.Rüzgar enerjisi rejimi hakkında net bilgi etkili planlama ve herhangi rüzgar enerjisi projesinin uygulanması açısından ön gereksinimdir.

Enerji tüketimi ve çevre kirliliği negatif sonuçları bakımından açıklığa kavuşmuştur.Yakıt tüketiminden rüzgar enerjisi,solar enerjisi,cezir ve akım enerjisi ve aktif kütle enerjisi gibi alternatif ve yenilenebilir enerji kaynaklarına dönüşüm gerekli bir hal almıştır.En az maliyetli v en uygun alternatif kaynaklar rüzgar enerjisidir.Elektrik gücünde yetersizlik sıkıntısı yaşayan Irak kent toplumlarında,elektrik enerjisi üretmek amacıyla kullanılabilen rüzgarlar vardır.Bizim araştırmamız,rüzgar gücü önemini ortaya çıkararak konuya uygun konuya tekniği kapsamaktadır. (Rüzgar hızı,yıllık elektrik üretimi ve kapasite etkeni) teknik analiz yöntemleri ile nasıl kullanılabileceğini,içeriklerini,sera gazı analizi,ekonomik analizler(Basit geri ödeme(SPB),net bugünkü değer(NPV) ve yaşam boyu tassaruf(ALCS)bu araştırmadaki veriler içindir. Al-Nasiriyah,Al-Amarah,Mandali ve Samara gibi Irak'ın tüm bölgelerini kapsayan dört şehirlerin seçerek rüzgar enerjisi potensiyelini araştırmaktayız.

Anahtar kelimeler:Rüzgar enerjisi projesi,rüzgar veri değerlendirilmesi,teknik analiz,sera gazi emisyon analizi,fiyat ve ekonomi analizleri

LIST OF ABBREVIATIONS

HAWT	:	Horizontal axis wind turbine
VAWT	:	Vertical axis wind turbine
CO2	:	Carbon Dioxide
GHG	:	Greenhouse Gases
KW	:	Kilowatt
W	:	Watt
KWh	:	Kilowatt hour
MWh	:	Megawatt hour
m	:	Meters
m/s	:	Meters per second
s	:	second
Kg	:	kilogram
Kg/ m^3	:	kilogram per cubic meter
t CO2	:	Tonnes of CO2
W/m2	:	Watt per square meter
O&M	:	Operations and Maintenance
SPB	:	Simple payback
NPV	:	Net present value
ALCS	:	Annual life cycle savings
$	:	United States Dollars
EMFs	:	Electromagnetic fields
WS	:	Wind speed
$/MWh	:	United States Dollars per Megawatt hour
$/yr.	:	United States Dollars per year
IRENA	:	International renewable energy agency
Yr.	:	Year
Yrs.	:	Years
SWERA	:	Solar and Wind Energy Resource Assessment
E3	:	Enercon 3000 kw
E2	:	Enercon 2000 kw
SAM	:	System Advisor Model software
RETScreen	:	Renewable-energy and Energy-efficiency Technology Screening software

LIST OF SYMBOLS

C_P	:	Power coefficient
$C_{P\,max}$	:	Betz limit
a	:	Axial induction factor
P	:	Power produced by the generator
ρ	:	Air density
A	:	Swept area of the blades
Ng	:	Generator efficiency
Nb	:	Gearbox efficiency
V	:	wind speed
Dia	:	Diameter of the blades
C_F	:	Capacity factor
KE	:	kinetic energy
m	:	Air mass
WP	:	wind power
WPD	:	Wind power density
C	:	Weibull scale parameter
k	:	Dimensionless Weibull shape factor
Γ	:	Gamma function
α	:	Wind shear exponent
Z	:	Height
$C_{(out;n)}$	:	Cash outflow
$C_{(in;n)}$	:	Cash inflow
$C_{(O\&M)}$	:	Yearly operation and maintenance cost
r_i	:	Inflation rate
C_{fuel}	:	Annual cost of fuel
r_e	:	Energy cost escalation rate
D	:	Annual debt payment
C_{per}	:	Periodic costs
n	:	Year
C_{ener}	:	Annual energy savings
C_{capa}	:	Annual capacity savings
r_{RE}	:	Credit escalation rat
C_{GHG}	:	GHG reduction income
r_{GHG}	:	GHG credit escalation rate
C_{RE}	:	Annual renewable energy (RE) production credit income
C	:	Total initial cost of the project
IG	:	Incentives and grants
C^{-}_{n}	:	After-tax cash flow
N	:	project life in years

CHAPTER ONE

INTRODUCTION

1.1 Context

Renewable energy sources are progressively becoming more alluring because of the negative effects of fossil fuels and because they can potentially reduce to zero or near to zero any greenhouse gases and any other toxic gases. Renewable energy sources, including sunlight based, wave, wind, hydro, tidal, geothermal and bio-mass are immediately accessible and they can provide a safe environment if used broadly [1][2] [3].

Wind power from renewable energy sources, in terms of abundance, cleanliness, and ease of use, has been widely used in the field of water transport, agriculture and industry. As evidenced by historical monuments, ancient Iraqis have used this energy in prehistoric times, where pottery and sailing boats dating back to the fourth millennium BC and beyond have been found. The Babylonians even built huge facilities to grind grain through connecting columns with huge stones that were rotated using the wind [4].

People have been harnessing the energy of the wind as far back as 5000 BC. The earliest known use was in Egypt, where wind had propelled boats along the Nile River. Wind has been the primary form of power for transportation across water until recent times. The work on the development of this energy has always been continuous with the windmill arriving in Europe in the 12th century, with mills having been built on a horizontal axis [5].

In Europe, the first windmill used to produce electricity was built in Scotland in July 1887 by Professor James Blyth, professor at the Faculty Anderson in Glasgow. The turbine had a height of 10 meters in the garden of a holiday house in Maricairk and it was used to charge batteries, developed by the Frenchman Camille Alphonse, to power the lighting in the cottage. Wind turbines were built to provide emergency power in cases of domestic asylum and service clinics [6].

1.2 Historical Development of The Use of Wind Power in Iraq

The Arab countries, including Iraq, enjoy intense, high-speed winds. However, the exploitation of this wind and its use is still limited to some countries, including Egypt, which is characterized by high wind speeds on its coastal belt.

Investments in wind power do not occur despite the availability of all the ingredients for success. Iraq is among the states in need of this energy because of the increasing need and urgency for electric power since 1991. The year 2004 saw the opening of the energy and fuel center at the University of Technology with its focus on a number of possibilities, including the renewable energy trends and applications of solar energy, wind energy and the study of renewable energy sources as alternatives in Iraq.

At the end of 2010, the Ministry of Electricity opened the Center for Renewable Energy and Environment in coordination with organizations and international companies in addition to Iraqi ministries and universities for the introduction of renewable energies in the sectors of production and distribution to support the national grid and provide electrical power to remote areas with different capabilities [4].

1.3 The Importance of the Iraq Sites

Iraq has a sufficient topography such that, throughout the year, the land and terrain allow the movement of greater than 5 m/s wind at a 10-meter height throughout the year. This is due to the fact that Iraq is located near the Arabian Peninsula, which is part of a low-pressure area and, in the winter, under the influence of high atmospheric pressure from Siberia, as well as from the north side of Turkey and the north-eastern and eastern side of Iran. In the summer, Iraq falls under the influence of nearly-stable, low atmospheric pressure in northwestern India and Central Asia to the north and north-west thus making Iraq an attractive area for wind in addition to the human possibilities, including the capital and lower costs of production as compared with other energy sources [4].

Another dominant factor in Iraq's climate is Iraq's distance from water bodies such as the Black Sea, the Red Sea, the Mediterranean Sea and the Caspian Sea, and as the Arabian Gulf is contiguous to Iraq in the south, it has little to no influence on wind speed, [4] as shown in Figure 1.1.

Figure 1.1: site of Iraq (wind atlas)

1.4 Basic Designs

Modern wind turbines classified into two general types: the horizontal-axis variety and the vertical-axis design. The horizontal-axis units are what we typically think of when discussing wind turbines; they look like large airplane propellers mounted on a tower. An alternative is the vertical-axis unit, which is sometimes called a Darrieus wind turbine after the French inventor, Georges Darrieus. A horizontal-axis turbine and a vertical-axis, Darrieus wind turbine, are shown in Figure 1.2 below [7] [8].

Figure 1.2: Types of wind turbine

1.5 The Aims of The Research

1- Selecting the most suitable sites in Iraq to extract their own wind data for the purpose of conducting the feasibility study and conducting the technical analysis necessary for the implementation of the project.

2- Feasibility assessment of the technical side:

- We will select the appropriate wind turbines for the best production of electric power at different speeds; even energy production at low speeds in order to ensure continuous power throughout the year by making comparisons between wind turbines from the same manufacturer but of different capacities in order to determine the best overall feasibility.
- Determining the appropriate hub height to capture the best wind speed with the wind turbines to achieve the maximum possible limit of power and electricity production for the national grid.

3- Assessment of the financial side: Through financial analyses, we will find the total initial costs required for installation and construction of the wind projects and the appropriate tariffs to recover capital and profits from wind station operation in the future.

4- Greenhouse gas (GHG) analysis: This factor is very important because of what currently ails the global environment in terms of increasing pollution levels and high rates of global warming, leading to the melting of the poles and the higher water levels, as well as the collapse of the ozone layer, all of which is important to global health.

1.6 Methodology

1- The selection of sites (Al-Nasiriyah, Al-Amarah, Mandali, and Samarra) for the feasibility assessment of the installation of a 75MW wind project.

2- Use of the RETScreen program to calculate the following for every project and every site:

- Annual energy and capacity factors
- Analyses of greenhouse gases
- Assessment of costs and finances to calculate Simple payback period (SPB), Net present values (NPV) and Annual life cycle savings (ALCS) for

each project.

3- The average annual wind speeds were extracted to 100m height using global atlas for renewable energy from international renewable energy agency (IRENA MAP)
4- The use of the SAM program to draw and distribute the layouts of turbines in the wind farm and to help calculate the area covered by the farm.
5- The use of wind roses to estimate the direction of the wind.

1.7 Highlight

- complete wind energy project assessment (technical and financial) in different sites in Iraq
- Effects of GHG reduction income on a wind energy project feasibility
- Minimum tariff required for a project to be feasible under different conditions

1.8 Structure of the Thesis

Chapter 1 reviews the introduction, types of wind turbines. Chapter 2 reviews the literature on wind energy, wind turbine theory, technical characteristics of wind turbines and Iraqi wind energy resources. Wind speed analyses, site selection, wind turbine selection and wind power plant technical assessments are presented in Chapter 3. Chapter 4 looks at the financial and cost analysis of the wind power plants, and conclusions are presented in Chapter 5. The thesis organization is shown diagrammatically in Figure 1.3.

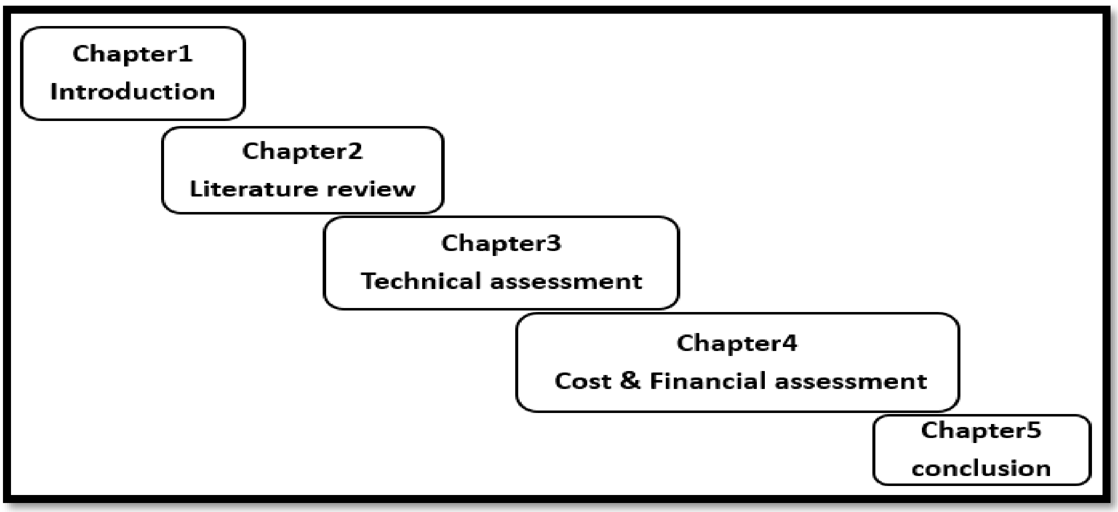

Figure 1.3: hierarchy scheme

CHAPTER TWO

LITERATURE REVIEW

Almost 90% of Iraqis are connected to the electricity grid, with over 80% of grid-supplied electricity coming from hydrocarbon-fueled power plants, almost 75% of which is crude-oil, heavy fuel oil or gas oil [9]. A small amount, less than 20%, comes from hydropower. Iraqis have increased their demand for power (through population growth and increased electricity requirements in homes and offices), but the reliability of supply is insufficient and reduced loads are a common daily experience for Iraqis [9]. Only in 2013 did the Iraqi power sector begin to approach pre-1991 Gulf War supply levels, with 9,000 MW of available generation capacity. In the meantime, electricity demand has almost tripled, from some 5,100 MW in 1991 to almost 17,000 MW today. A workshop of Iraq stakeholders (UNDP-facilitated, the Ministry of Electricity November 2011) revealed an extensive understanding that the reliability and capacity of Iraq's electricity supply have fallen in the past two decades, a finding confirmed by a recent Al Jazeera survey of Iraqis that found most experience several hours of grid outages each day. Iraq's present electricity shortages are estimated to cost $40 billion per year, compared with Iraq's GDP of $200 billion for 2012.

The Iraqi power sector is owned and operated by the Iraqi Ministry of Electricity (MoE). There are three departments within the Ministry of Electricity – Generation, Transmission and Distribution – that are responsible for generating electricity and delivering it to end-users. About 50% of overall electricity demand is due to air conditioning in the summer season and electric heaters and heating in the winter. Iraq is one of the hottest countries in the world (with summer temperatures of between 45ºC and 55ºC), and summer temperatures are steadily increasing. People in Baghdad are especially desperate to purchase air conditioners, and hopefully have enough electricity to use them, as noted frequently in the media. The lack of electricity during the critical summer months affects national productivity and makes it difficult to work in the stifling heat [9].

2.1 Renewable Energy

Presently, known renewable sources of energy in addition to nuclear energy, are alternatives to energy production from fossil fuels as well as reducing electricity production from fossil fuels. Knowing that there exist many social and environmental complications with nuclear energy, renewable energy becomes a major element in security and power production in the world [3]. Many renewable energy sources are desirable due to their contributions to greenhouse gas reduction. Formal definitions of renewable energy sources vary from country to country; however, there is broad agreement that renewable energy includes wind energy, solar photovoltaic energy, and solar thermal energy. Other sources that are often considered renewable include hydropower, tidal power, wave power, geothermal power and biomass. The increasing dependence on renewable energy sources is complicated by various barriers to implementation. Most renewable energy technologies face cost disadvantages in comparison with conventional energy technologies [10]. Roads to and from the plant site and transmission roads and clearings for transmission lines, are common to all electricity-generating facilities. Others factors, such as specific aesthetic impacts, are exclusive to wind-energy amenities, from regional to global scales [11] [12].

Renewable energy can be defined in many ways; however, it can generally be defined as being sourced from infinite and continuously available sources (which do not rely on fossil fuel such as coal, oil and gas or nuclear power), or it can be defined as energy flows that are renewed at equivalent rates as they are used. Renewable energy may be classified as follows:

1- Non-solar renewable energy: This type of energy is not powered by the sun directly or indirectly, and comprises only tidal and geothermal energy.
2- Solar renewable energy: This category consists of various types of energy produced by the sun directly or indirectly. Solar radiation for heating and electricity generation can be categorized as direct solar renewable energy. However, indirect solar renewable energy includes an extensive range of renewable energy forms, such as hydropower, wind energy, wave energy, ocean thermal energy as well as biomass and bio fuel [13].

2.2 Wind Energy

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun as shown Figure 2.1

1- The original source of the renewable energy contained in the earth's wind resource is the sun.
2- Global winds are caused by pressure differences across the earth's surface due to the uneven heating of the earth by solar radiation.
3- For example, the amount of solar radiation absorbed at the earth's surface is greater at the equator than at the poles.
4- The variation in incoming energy sets up convective cells in the lower layers of the atmosphere (the troposphere).
5- The circulation of the atmosphere that results from uneven heating is greatly influenced by the impacts of the rotation of the earth.
6- In addition, seasonal variations in the distribution of solar energy give rise to variations in the circulation.
7- The spatial variations in heat transfer to the earth's atmosphere create variations in the atmospheric pressure field that cause air to move from high to low pressure.
8- There is a pressure gradient force in the vertical direction, but this is usually cancelled by the downward gravitational force.
9- Thus, the winds blow predominately in the horizontal plane, responding to horizontal pressure gradients.
10- At the same time, there are forces that struggle to mix the different temperature and pressure air masses distributed across the earth's surface.
11- In addition to the pressure gradient and gravitational forces, inertia of the air, the earth's rotation, and friction with the earth's surface (resulting in turbulence), affect the atmospheric winds.
12- The effect of each of these forces on atmospheric wind systems varies depending on the size of motion considered [14,15,16].

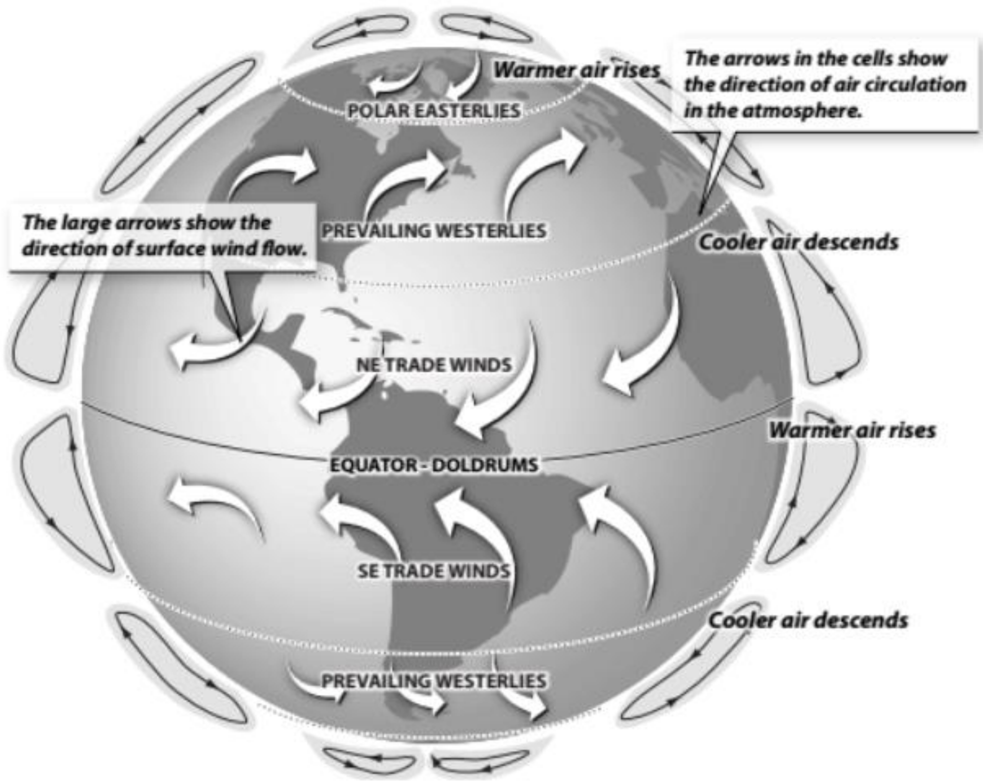

Figure 2.1: Surface winds of worldwide circulation pattern

2.3 Wind Power History

Wind power is not a new invention. For several decades, humankinds have been using windmills and watermills as sources of power to drive a number of mechanical applications. These windmills mainly were used to ground grains and for irrigation or drainage. However, the appearance of the simplest wind devices goes back to thousands of years when vertical axis windmills found at the Persian- Afghan borders around 200 BC. After a long time between 1300 and 1875 AD, the horizontal axis windmills appeared in Netherlands and around the Mediterranean Sea zone. Real development and improvement of these systems appeared in the USA during the 19th century. The revelation proved by using over 6 million of these systems for water pumping between 1850 and 1970 [17] [18] [19].

In 1888, first wind turbine, used for generating electricity with 12 KW as capacity was installed in Cleveland, Ohio. In meanwhile, the use of 25 KW turbines in Denmark during the last stage of World War I was widespread. In the period between 1935 and 1970, the great efforts in Denmark, Germany, UK and France proved that large-scale wind turbines could be used. After World War II, the European efforts continued in developing the large scale of wind turbines that was seen clearly in Denmark when the Gedesr mill 200 KW with three-bladed upwind rotors wind turbine operated successfully until the early 1960s. However, further series of advanced horizontal-axis designs were developed in Germany until the 70s [19].

In 1973, the oil crises have a positive effect on the United State government's decisions related to the increase of the efforts and involvements in wind energy research and development sector. These efforts are considered as the essential backbone in the near history of wind energy developments. From 1973 to 1986 new concept of the commercial wind turbine market developed from agricultural and domestic to utility interconnected wind farm applications. As result of this new concept was the first wind large scale farm penetration in California where over 16000 wind turbines ranging from 20 to 350 KW were installed between 1981 and 1990 to achieve a 1,7 GW as total capacity. After 1990 most of the market development and activities shifted to Europe, which can be considered as one of main market leaders with other regions in the last twenty years [18] [19].

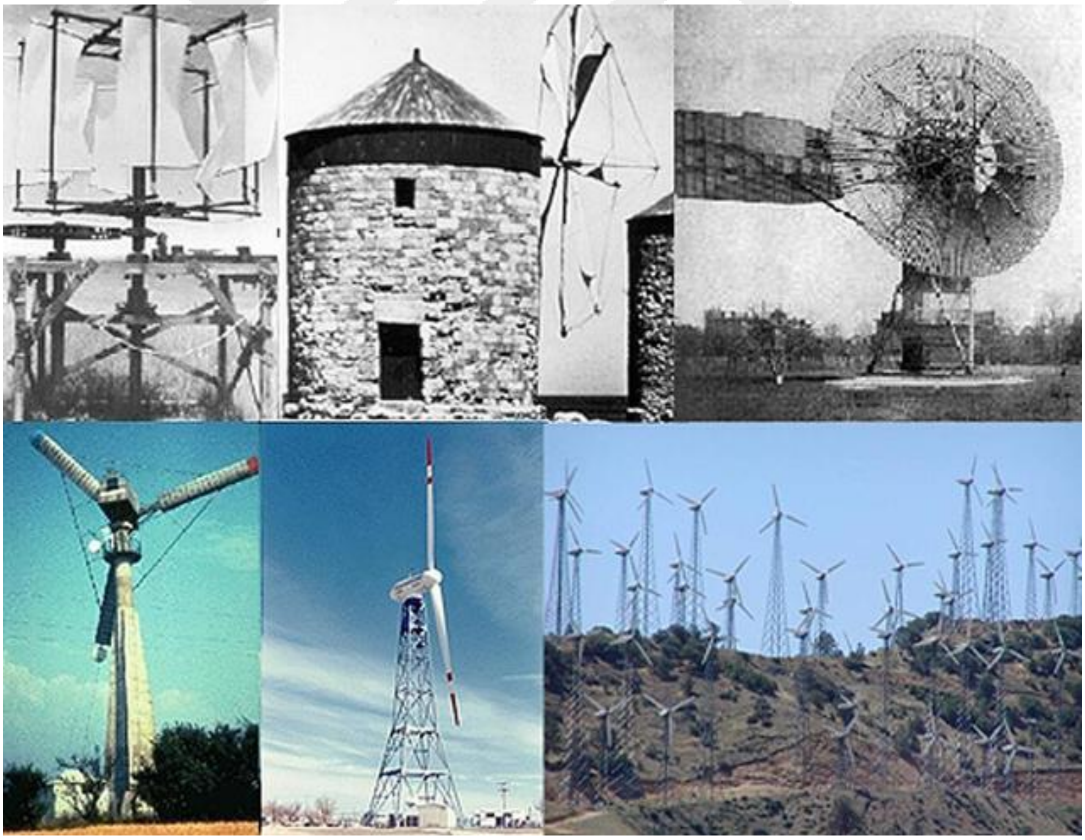

Figure 2.2: Pictures for windmills from the early stages of wind energy exploitation to the outbreak of California [19]

2.4 Operating Characteristics

A few of the important operating characteristics of a wind turbine include the cut-in speed, rated speed, cut-out speeds, power output and capacity factor.

2.4.1 Cut-in Speed

this is the minimum wind speed at which the turbine blades overcome friction and begin to rotation and generate electrical power, the cut-in speed for modern wind turbines is generally around (2- 4)m/s [20] [21] [7].

2.4.2 Rated Speed

Rated speed means the wind turbine achieve maximum power production and this energy stay constant although increase speed of wind above rated speed. Typically somewhere between 12 and 17 metres per second, At wind speeds between cut-in and rated, the power output from a wind turbine increases as the wind increases. The power output of a wind turbine is relatively flat above its rated speed until the wind speed reaches the cut-out speed [21] [7].

2.4.3 Cut-out Speed

Above a certain speed, the wind turbine will need to shut down and cease operation to prevent damage to the unit. This is called the cut-out speed and is usually around 25 metres per second. The most common method of shutting down a wind turbine is for the blades to change pitch so that the wind just passes through the blades without producing lift. Other methods include turning the units parallel to the wind or the use of some type of drag device that prevents the blades from turning in the high winds [21][7].

2.5 Betz Limit

Albert Betz was a German physicist who calculated that no wind turbine could convert more than 59.3% of the kinetic energy of the wind into mechanical energy turning a rotor. This is known as the Betz Limit, and is the theoretical maximum coefficient of power for any wind turbine [22] [23].

$$\boldsymbol{C_P = 4a(1-a)^2 \quad with\ C_{P\,max} = \frac{16}{27} = 0.593}$$ .... (1)

2.6 Power Coefficient

The power coefficient depends on how good a turbine is in design and how well it can grasp the wind energy. Thus, its value can be small or large Nevertheless, there is a maximum value that no turbine in its best performance can exceed. It can be theoretically determined and is called the Betz limit. The value for Betz limit is 16/27 (0.59) [24].

$C_{P=}Power\ of\ a\ wind\ turbine/Power\ in\ the\ wind$ .... (2)

2.7 Power Output

The power generated by a wind turbine can be found using the following formula [7],

P = 0.5 * ρ *A * Cp * Ng * Nb * V^3 .... (3)

Where,

P = Power produced by the generator, watts

ρ = Air density, kg/m^3

A = Swept area of the blades, m^2

Cp = Power coefficient

Ng = Generator efficiency

Nb = Gearbox efficiency

V = wind speed, meters/sec

2.8 Capacity Factor

The capacity factor of a wind turbine is actual energy output of a wind turbine during a given time period, usually one year, compared to its theoretical maximum energy output. The capacity factor is [7],

$$C_F = \frac{Energy\ Estimated}{(Plant\ Generator\ Name\ plate\ capacity\ x\ 24\ Hours\ x\ 365\ Days\,)}$$ .... (4)

Where, C_F = Capacity factor

Typically, wind turbines have capacity factors of between 20-35% for units located with good wind capacity [25].

2.9 The Wind Power

Calculations of wind power are derived from the equation for kinetic energy (KE), which is:

$$KE = \frac{1}{2} m v^2 \text{ ………. (5)}$$

Where m is mass, v is acceleration, Air mass is equal to the product of its density and volume. Volume is dependent on the area through which the air is passing, the speed with which it is moving, and the amount of time it travels. Air mass can therefore be calculated as:

$$m = \rho . A . v . t \text{ ………. (6)}$$

Where ρ is the air density, A is the area through which the air passes, v is wind speed and t is time? Since power is energy divided by time, the equation for wind power (WP) can be written as[24] [22]:

$$WP = \frac{1}{2} \rho . A . v^3 \text{ ………. (7)}$$

2.10 Wind Power Density

Wind power density is the amount of wind power available per unit of area perpendicular to the wind flow. In practice, wind power density is used to estimate the potential electrical output of a wind farm [26]:

$$WPD = \frac{1}{2} \rho v^3 \text{ ………. (8)}$$

The best wind capacity is the density of wind capacity (Wind Power Density), because it will give a clear picture of how to distribute wind speed on average (mean) and this quantity can be estimated in practice by using (Weibull Distribution) which it depends on the two parameter (c) scale and (k) shape parameters, where Γ Gamma function [27] [28]:

$$WPD = \frac{1}{2} \rho C^3 \Gamma \left(\frac{1+3}{K}\right) \text{ ………. (9)}$$

2.11 Vertical Estimation of Wind Speed Using the Power-Law Model

As described above, winds are slowed by friction at the earth's surface, so that wind speeds tend to be greater at higher elevations. For regions with relatively level terrain and little vegetation, the method most commonly used to obtain this extrapolation is the 1/7 power-law model. The equation of the 1/7 power-law model is:

$$\frac{v\,(Z)}{v\,(Z_0)} = (\frac{Z}{Z_0})^{\alpha} \text{ ………. (10)}$$

Where Z is the height at which the wind speed is to be estimated $v\,(Z)$, and $v\,(Z_0)$ at the reference height Z_0, (α) wind shear exponent respectively [29] [30].

Table 2.1: illustrate Friction coefficient of various terrains

Table 2.1: friction coefficient of various terrains

Terrain Type	**Friction Coefficient α**
Lake, ocean and smooth hard ground	0.10
Foot high grass on level ground	0.15
Tall crops, hedges and shrubs	0.20
Wooded country with many trees	0.25
Small town with some trees and shrubs	0.30
City area with tall buildings	0.40

2.12 Potential Environmental and Social Impacts of Wind Power Development

2.12.1 Sound and Noise

Sound is characterized by its sound pressure level (loudness) and frequency (pitch), which are measured in standard units known as decibel (dB) and Hertz (Hz), respectively, Wind turbines generate sound through mechanical and aerodynamic routes. The sound level depends on various factors including design and wind speed. Current generation upwind model turbines are quieter than older downwind models. The dominant sound source from modern wind turbines is aerodynamic, produced by the rotation of the turbine blades through air. The aerodynamic noise is present at all frequencies, from infrasound to low frequency to the normal audible range, producing the characteristic “swishing” sound [31] [32].

2.12.2 Electromagnetic Fields (EMFs)

Wind turbines are not considered a significant source of EMF exposure since emissions levels around wind farms are low [32] [33].

2.12.3 Shadow Flicker

Shadow flicker occurs when the blades of a turbine rotate in sunny conditions, casting moving shadows on the ground that result in alternating changes in light intensity appearing to flick on and off. About 3 per cent of people with epilepsy are photosensitive, generally to flicker frequencies between 5-30Hz. most industrial turbines rotate at a speed below these flicker frequencies [32].

2.12.4 Ice Throw and Ice Shed

Depending on weather conditions, ice may form on wind turbines and may be thrown or break loose and fall to the ground. Ice throw launched far from the turbine may pose a significant hazard. Ice that sheds from stationary components presents a potential risk to service personnel near the wind farm. Sizable ice fragments have been reported to be found within 100 meters of the wind turbine. Turbines can be stopped during icy conditions to minimize the risk [32].

2.12.5 Structural Failure

The maximum reported throw distance in documented turbine blade failure is 150 meters for an entire blade, and 500 meters for a blade fragment. Risks of turbine blade failure reported in a Dutch handbook range from one in 2,400 to one in 20,000 turbines per year. Injuries and fatalities associated with wind turbines have been reported, mostly during construction and maintenance related activities [33].

2.12.6 Bird Strikes

Since wind turbine blades generally work at high altitudes, birds can fly into fast-moving rotor blades and bekilled [34].

2.12.7 Visual Impacts

The presence of wind turbines produces changes in views and skylines, and therefore, has a visual impact on the area in which they are cited. Visual impacts may be an especially important consideration if the turbines are to be located in pristine or wilderness areas. The access roads and power lines needed for grid-connected turbines can cause additional aesthetic impacts [35] [32].

2.12.8 Interference with Telecommunications

Wind turbines normally interfere with television and other telecommunications signals, but these impacts seem to be typically localized to the vicinity of the wind farm [31] [35].

2.12.9 Safety

Like any industry that includes moving machinery, safety is an issue with wind farms. Particular hazards from equipment failure include injury from equipment failures such as blades breaking off [35].

2.13 RETScreen Clean Energy Management Software

1- RETScreen is a Clean Energy Management program system for power efficiency, renewable energy and cogeneration project feasibility analysis as well as continuing energy performance analysis and software package developed by the Government of Canada. RETScreen Expert was highlighted at the most recent Clean Energy Ministerial held in San Francisco in June 2016 [36].

2- RETScreen Suite, comprising RETScreen 4 and RETScreen Plus, is the previous version of the RETScreen software. RETScreen Suite includes cogeneration and off-grid analysis capabilities, Unlike RETScreen Suite, RETScreen Expert is one integrated software platform; utilizes detailed and comprehensive archetypes for assessing projects; and includes portfolio analysis capability. RETScreen integrates a number of databases to assist the user, including a global database of climatic conditions obtained from 6,700 ground-based stations and NASA satellite data; benchmark database; cost database; project database; hydrology database and product database [37], The software contains extensive integrated training material, including an electronic textbook

3- History: The first version of RETScreen was released on April 30, 1998. RETScreen Version 4 was launched on December 11, 2007 at Bali, Indonesia by Canada's Minister of the Environment, RETScreen Plus was released in 2011, RETScreen Suite (integrating RETScreen 4 and RETScreen Plus with numerous additional upgrades), was released in 2012, RETScreen Expert was released to the public on September 19, 2016 [38].

4- Examples of use: As of October 2016, the RETScreen software had more than 490,000 users in 222 countries and territories worldwide RETScreen is widely used to facilitate and implement clean energy projects. For example, RETScreen has been used

- To retrofit the Empire State Building with energy efficiency measures.
- Extensively by the Irish wind industry to analyse potential new project.
- Manitoba Hydro's combined heat & power (bioenergy optimization) program to screen project applications.
- In a multi-year assessment and evaluation of photovoltaic performance in Toronto, Canada.
- To identify opportunities for energy efficiency retrofits in various Ontario municipalities [39].

5- Awards and recognition: in 2010, RETScreen International was awarded the Public Service Award of Excellence the highest award given by the Canadian government to its civil servants, RETScreen and the RETScreen team have been nominated for and received numerous other prestigious awards including the Ernst & Young/Euro money Global Renewable Energy Award, Energy Globe (National Award for Canada), and the GTEC Distinction Award Medal [37].

2.14 Previous Studies by Retscreen Program

2.14.1 Techno-Economic Study for 50 MW Wind Farm in Gwadar Coastal City of Baluchistan-Pakistan using ARIMA Model and RETScreen

this paper study take wind data from Pakistan Meteorological and used ARIMA program to analysis data.

- Use the wind turbine type with a cut in speed less than 4m/s to guarantee generate electricity at low wind speed.
- Technical evaluation and financial assessment in the RETScreen software to estimate the feasibility of installation and construction of wind power station 50MW in Baluchistan site Without taking into account the rate real wind speed depending on IRR and the price of device.
- Investment feasibility analysis depending on the hub height of turbines in order to get a high wind speed to determine the chances for success of the project.
- In this article, absence the issue of the greenhouse gasses analysis and their impact on the climate and environmental [40].

2.14.2 Energy Transitions in Kenya's Tea Sector: A Wind Energy Assessment

Economic analysis using RETScreen to find Net present value (NPV) under a wide range of assumptions. using SWERA atlas to extract wind resources [41].

2.14.3 Wind Energy for Rural Areas of Algeria

The annual wind energy production and capacity factor, obtained using wind speed frequency distribution and wind power curve of 1000 kW wind turbine and RETScreen software were found comparable with each other if unadjusted energy production values calculated by the software were used rather than the renewable energy delivered [42].

2.14.4 Financial Viability of Grid-Connected Solar PV And Wind Power Systems in Germany

using The Canadian RETScreen Clean Energy Project Software to aim analysis technical to estimate energy production, financial feasibility, GHG emission reductions potentials and calculate costs for the project [43].

2.15 Wind Power in Iraq

Distribution of wind farms in Iraq: To apply the distribution of the wind farms along the country measurements for the average wind speed (monthly and annually) in some areas must be studied to give the appropriate decision of choosing the suitable areas for this purpose. Table 2.2 gives the actual wind speed (m/s) in Iraqi governorates [44].

Table 2.2: Monthly wind speed for some sites in Iraq

site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des	Annaual
Nasiriya	4.7	5.1	5.6	5.7	6.1	6.5	6.1	5.9	5.5	5.2	4.8	4.9	5.55
Amarah	4.7	4.8	4.9	5.3	6.1	6.5	5.9	5.9	5.9	5.5	5.1	4.9	5.52
Mandali	4.6	4.9	5.2	5.3	5.7	6.1	5.8	5.7	5.5	5.3	4.8	4.7	5.36
Samarra	4.4	4.8	5.2	5.3	5.5	6.2	6.5	6.3	5.5	4.9	4.3	4.3	5.31

The annual average distribution of the wind speed and direction in Iraq for the period of (1996-2015) is shown in Figure (2.3, 2.4).

Figure 2.3: Annual average distribution of wind speed

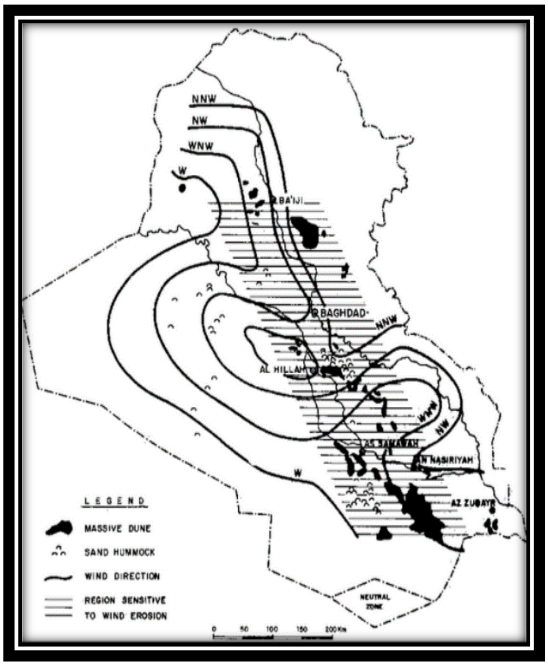

Figure 2.4: (Wind direction in Iraq)

CHAPTER THREE

TECHNICAL ASSESSMENT AND GREENHOUSE GASES ANALYSIS

3.1 Determining the Type of Wind Turbine

We will select the Enercon-E82 wind turbine as it works to produce electricity at a cut-in speed of less than 3 m/s. Therefore, there is the possibility of these turbines producing electricity at low speeds as they have annular generators without a gear box and they have a hub height of more than 70 m in order to capture high wind speeds. For approximately every 1-meter increase in the hub-height of a farm wind turbine, the annual energy production increases by 0.5%. Therefore, it is always financially better to opt for the highest tower available, provided planning consent for the higher tower can be obtained [45].

3.2 Technical Specifications for The Enercon-E82 (E3-3000, E2-2000) Kw Wind Turbine (Germany)

Analyses are carried out using the RETScreen software using two types of Enercon E82 wind turbine (Enercon E82-E3-3000 Kw, Enercon E82-E2-2000 Kw) with hub height (78, 85, 98, 108 and 138 m) as shown in Figure (3.1, 3.2) and table 3.1 for the 75MW wind energy projects at each site (Al-Nasiriyah, Al-Almarah, Mandali and Samarra) for the purpose of comparing the technical aspects, GHG emission, costs, financial and area occupied by the wind farm.

Figure 3.1: Wind turbine Enercon - E82

Table 3.1: Specification of Enercon E82 (3000,2000) KW wind turbine

Item	Enercon E82 – 2000 kW	Enercon E82 – 3000 kW
Configuration	Three blade	
horizontal axis	upwind	
Rated Power	3.000 kW at 16m/s	2.000 kW at 13m/s
Rotor Speed	6 to 18 RPM	
Turbine Class	IEC 61400-1: IIA	
Survival Wind Speed	59.5 m/s	
Rotor	Rotor Diameter: 82 m Swept Area: 5,281 m²	
WEC concept	Gearless, variable speed, Single blade adjustment	
generator	ENERCON direct-drive annular generator Generator Type: The annular generator - comprising rotor and stator - forms the key component of the ENERCON wind energy converter design. Configuration: 3-Phase, 400V, 50Hz – 60Hz	
Grid feed	ENERCON inverter	
Towers	78 m, 85 m, 98 m, 108 m, 138 m [45, 46, 47]	

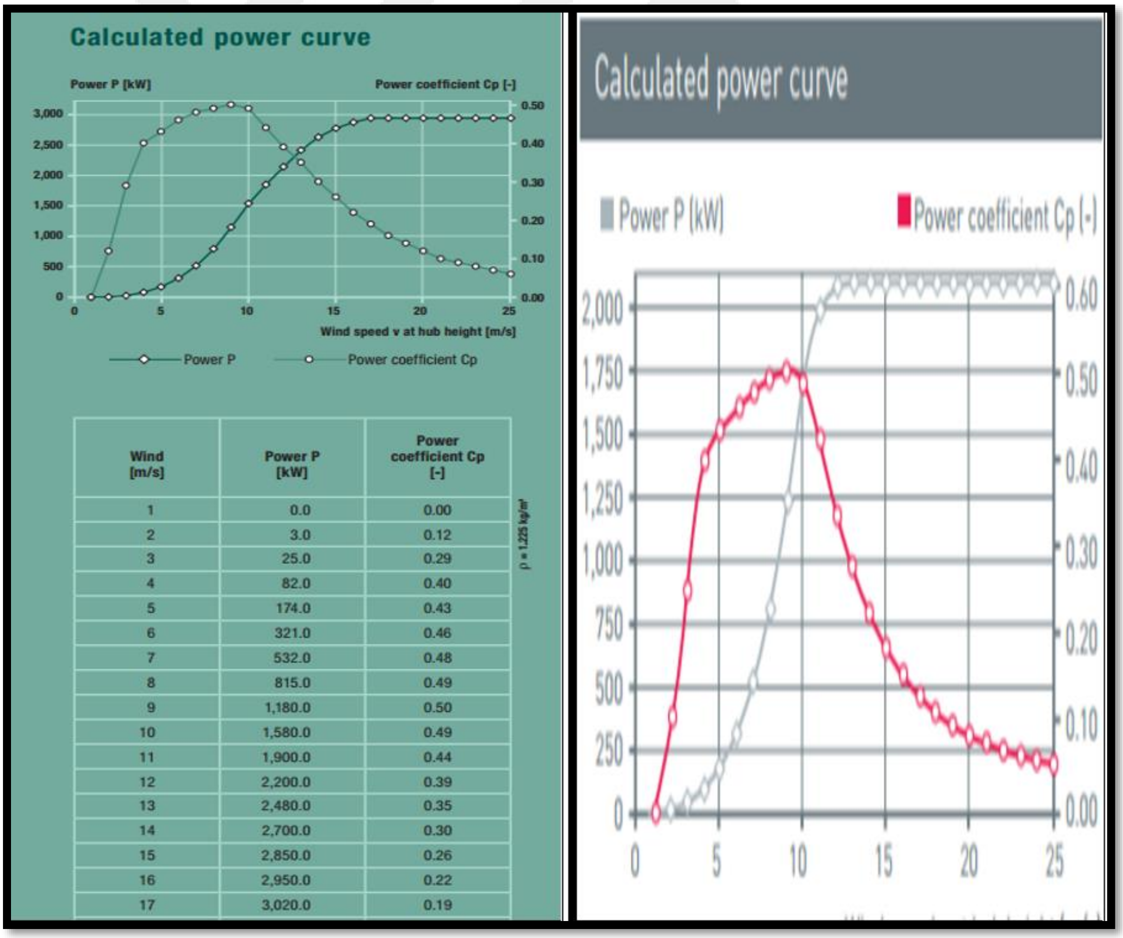

Figure 3.2: Power curve for wind turbine Enercon (3000, 2000) KW [45, 46, 47]

3.3 Technical Assessment for Wind Energy Project with the RETScreen Software

The RETScreen wind energy project model is used internationally to evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for wind energy projects, ranging in size from large-scale multi-turbine wind farms to small-scale single-turbine wind power systems [48].

3.3.1 Energy Model

In this worksheet, the user specifies the parameters describing the location of the energy project, the type of system used in the base case, the technology for the proposed case, the loads (where applicable), and the renewable energy resource (for RETs). In turn, the RETScreen software calculates the annual energy production or energy savings. Often a resource worksheet (such as the "Solar Resource" or the "Wind Resource" worksheet) or an "Equipment Data" worksheet – or both – accompanies the Energy Model worksheet as a sub-worksheet or worksheets, as shown in Figure 3.3 below [48].

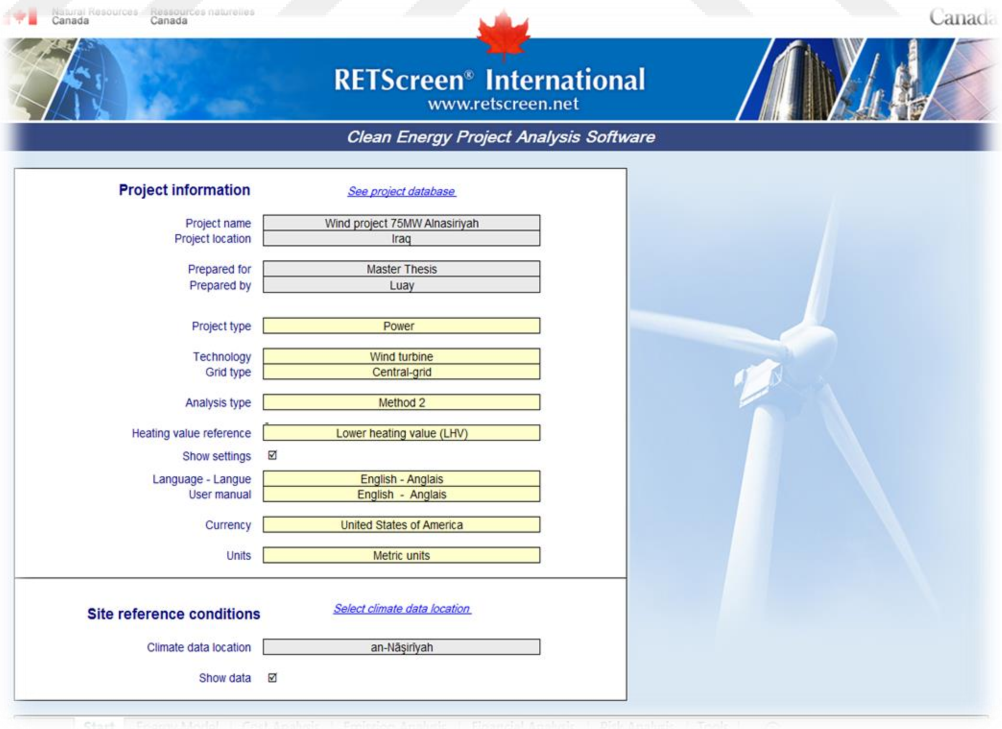

Figure 3.3: RETScreen wind turbine project model interface

Table 3.2 and Fig 3.4 shows input and output data for RETScreen software

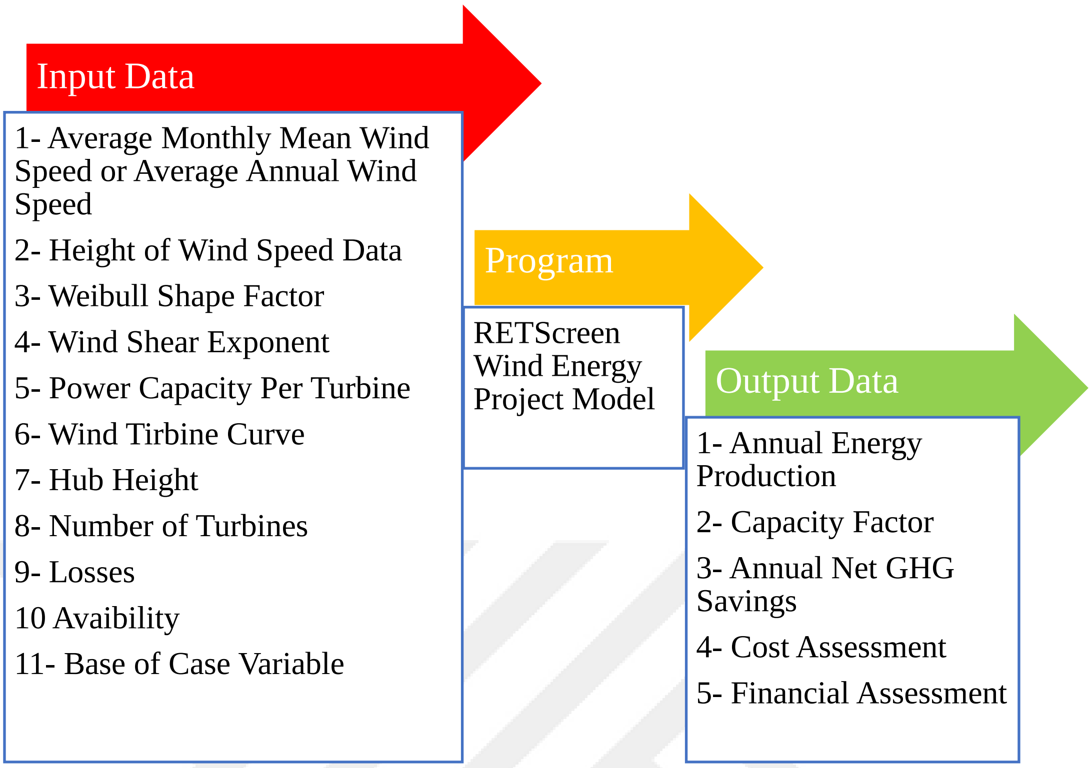

Figure 3.4: input and output data for RETScreen software

Array losses: These are caused by the interaction of multiple wind turbines with each other through their wakes. Turbines in the "shadow" of others do not "see" as much wind as the front ones and energy production is decreased as a result. Array losses depend on the turbine spacing, orientation, site characteristics and topography.

Airfoil losses: Airfoil soiling losses are caused by soiling of the blades from such things as bugs and/or ice build-up. Accumulation of bugs or ice affects the aerodynamic performance of the blades. It can be improved by washing the blades regularly or heating the edge of the blades. Icing losses occur when an accumulation of ice forces a wind machine to shut down or prevents it from starting. Icing losses depend on the ambient temperature, the altitude at which the machine is installed, the level of humidity and the machine design.

Miscellaneous losses: represents losses of energy production due to starts and stops, off-yaw operation, high wind and cut-outs from wind gusts. They also include any parasitic power requirements and any transmission line losses from the wind energy project site to the point where the project connects to the local distribution grid.

Availability: Represents downtime losses are the result of scheduled maintenance, wind turbine failures, station outage and utility outage. Typical values range from 93 to 98% of "Gross energy production." In the case of wind turbines installed in extreme environments (arctic climate, weak grid, etc.) [48].

Table 3.2: Input data for RETScreen program

Item	Enercon -E82-E3-3000KW	Enercon -E82-E2-2000KW
Array losses	12%	15%
Airfoil losses	6%	8%
Miscellaneous losses	4%	6%
Availability	96%	96%
NO. of unit	25	38
Shape factor (standard)	2	2
Wind shear exponent	0.14	0.14

3.3.2 Site Selection

Four regions were selected in Iraq (Al-Nasiriyah, Al-Amarah, Mandali and Samarra) see Figure 3.5 to assess the technical and financial feasibility of establishing wind projects in those areas for the following reasons:

1- These sites have the best data for wind in Iraq.
2- The sites have vast empty land, without any natural obstacles in them, thereby providing smooth movement of wind.
3- It encourages investment by local governments in these areas for the purpose of providing employment opportunities.

Figure 3.5: Site of projects

3.4 Technical Assessment of Annual Electricity Generation and Capacity Factor Versus Hub Height for All Chosen Sites

3.4.1 Al-Nasiriyah Site (Technical Assessment)

- Annual wind speed at 10m height = 5.55m/s [49], see Figure 3.6**.**
- Annual wind speed at 100m height = 7.5m/s [50]**.**

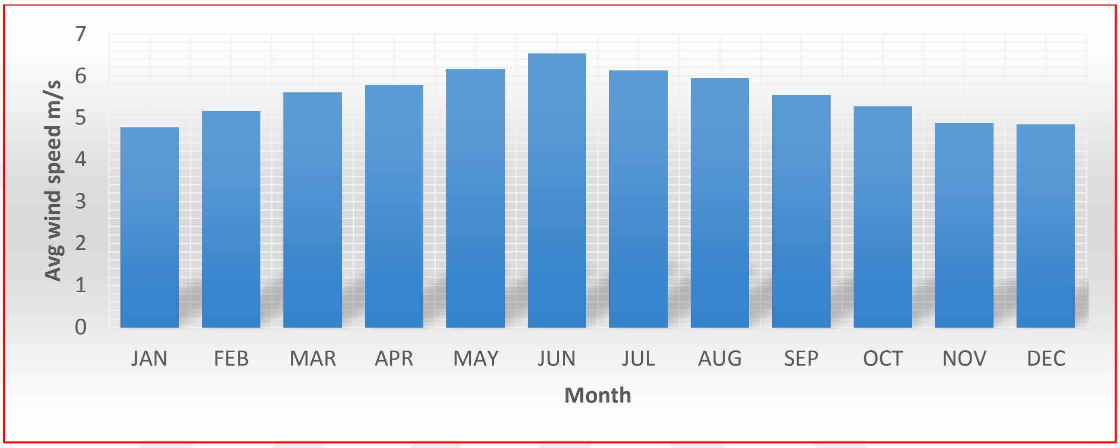

Figure 3.6: Monthly wind speed at the Al-Nasiriyah site at height 10 meters

Table 3.3 illustrates the calculations of annual electricity production with the capacity factor for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at Al-Nasiriyah site and as the follow.

a- For the 75MW wind project with the Enercon-E82-E3-3000 kW/25-unit:

An analysis by the RETScreen software using the Enercon-E82-E3-3000 kW wind turbine at the Al-Nasiriyah site shows the annual electricity exported to the grid from the wind power project produced 134,621 MWh of the energy at a 78-meter hub height with a capacity factor of 20.5%, increasing to 137,827 MWh at an 85-meter hub height with a capacity factor of 21%, then increasing to 143,221 MWh at a 98-meter hub height with a capacity factor of 21.8%. It then rises to 146,966 MWh at a 108-meter hub height with a capacity factor of 22.4% and reaching 156,644 MWh at a 138-meter hub height with a capacity factor of 23.8% as illustrated in Figure (3.10 ,3.12, 3.13).

b- For the 75MW wind project with the Enercon-E82-E2-2000 kW/38-unit:

Analysis from the RETScreen software using the Enercon-E82-E2-2000 kW wind turbine at the Al-Nasiriyah site for the annual electricity exported to the grid from the wind power project shows that it produced 171,219 MWh of energy at a 78-meter hub height with a capacity factor of 25.7%, increasing to 174,668 MWh at an 85-meter hub height with a capacity factor of 26.2%, which then increases to 180,471 MWh at a 98-meter hub height with a capacity factor of 27.1%. It then rises to 184,499 MWh at a 108-meter hub height with a capacity factor of 27.7% and reaching 194,909 MWh at a 138-meter hub height with a capacity factor of 29.3% as illustrated in Fig. (3.11, 3.13).

Table 3.3: Annual electricity generation and capacity factor versus hub height for both types of wind turbine Enercon (3000, 2000) kW at the Al-Nasiriyah site

Hub height (m)	Enercon -E82-E3-3000KW			Enercon -E82-E2-2000KW		
	the annual electricity exported to grid (MWh)	capacity factor (%)	Number of turbines	the annual electricity exported to grid (MWh)	capacity factor (%)	Number of turbines
78	134,621	20.5	25	171,219	25.7	38
85	137,827	21		174,668	26.2	
98	143,221	21.8		180,471	27.1	
108	146,966	22.4		184,499	27.7	
138	156,644	23.8		194,909	29.3	

3.4.2 Al-Amarah Site (Technical Assessment)

- Annual wind speed at 10m height = 5.53m/s [49], see Figure 3.7.
- Annual wind speed at 100m height = 7.1m/s [50].

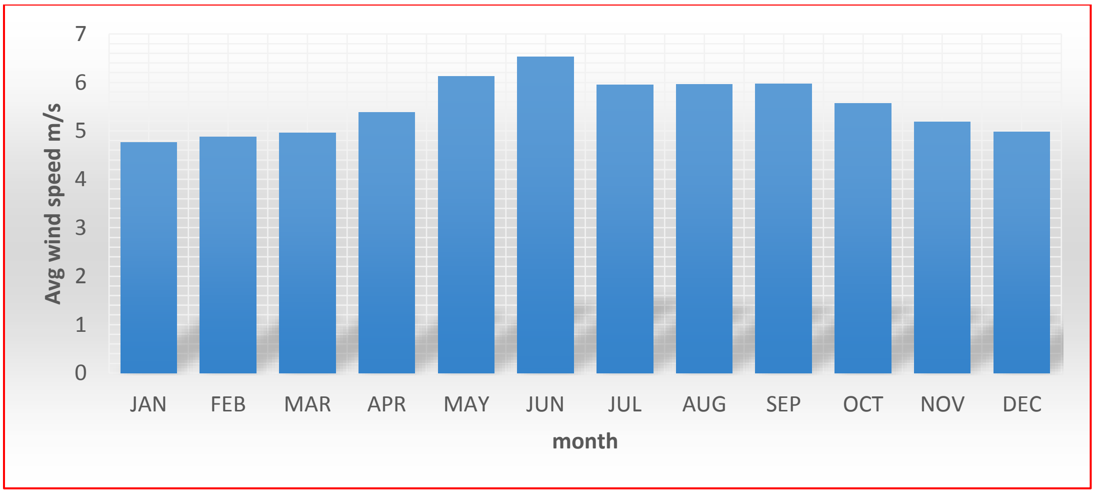

Figure 3.7: Monthly wind speed of the Al-Amarah site at a height of 10 meters

Table 3.4 illustrates the calculations of the annual electricity production with capacity factors for the projects using the Enercon E82-(3000, 2000) kW wind turbines using the RETScreen program at the Al-Amarah site, where we note a gradual rise of the value of the produced energy from the wind plant with increased hub heights, as shown in Figure (3.10, 3.11, 3.12, 3.13)

Table 3.4: Annual electricity generation and capacity factor versus hub height for both types of wind turbine Enercon (3000, 2000) kW at the Al-Amarah site

Hub height (m)	Enercon -E82-E3-3000KW			Enercon -E82-E2-2000KW		
	the annual electricity exported to grid (MWh)	capacity factor (%)	Number of turbines	the annual electricity exported to grid (MWh)	capacity factor (%)	Number of turbines
78	120,117	18.3	25	155,065	23.3	38
85	123,152	18.7		158,606	23.8	
98	128,251	19.5		164,289	24.7	
108	131,786	20.1		168,091	25.2	
138	140,920	21.4		177,916	26.7	

3.4.3 Mandali Site (Technical Assessment)

- Annual wind speed at 10m height = 5.36m/s, see Figure 3.8.
- Annual wind speed at 100m height = 6.69m/s.

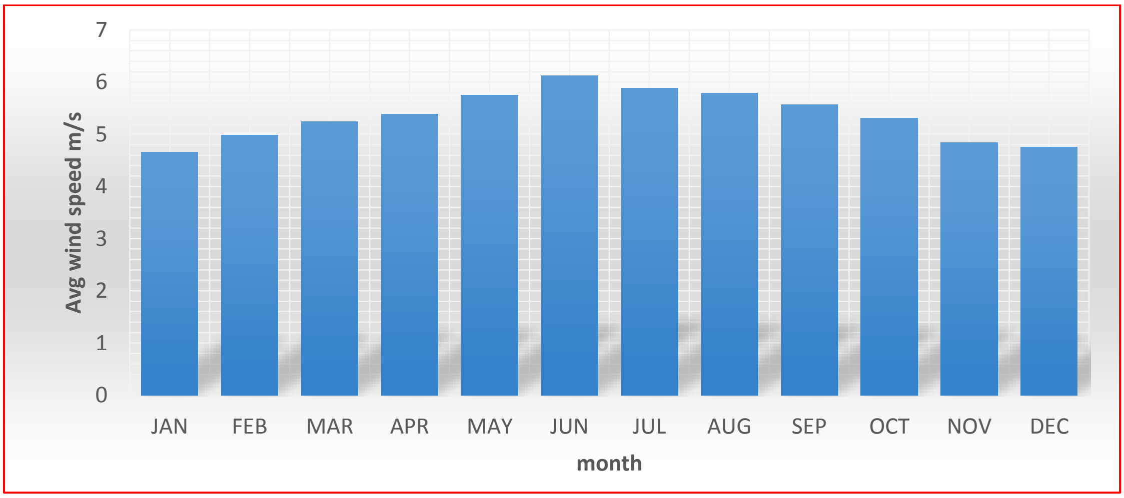

Figure 3.8: Monthly wind speed of the Mandali site at a height of 10 meters

Table 3.5 illustrates the calculations of annual electricity production with the capacity factor for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at Mandali site, as shown in Figure (3.10, 3.11, 3.12, 3.13).

Table 3.5: Annual electricity generation and capacity factors versus hub height for both types of wind turbine Enercon (3000, 2000) kW at the Mandali site

Hub height (m)	Enercon -E82-E3-3000KW			Enercon -E82-E2-2000KW		
	the annual electricity exported to grid (MWh)	capacity factor (%)	Number of turbines	the annual electricity exported to grid (MWh)	capacity factor (%)	Number of turbines
78	103,064	15.7	25	134,811	20.2	38
85	105,855	16.1		138,066	20.7	
98	110,551	16.8		143,544	21.6	
108	113,811	17.3		147,346	22.1	
138	122,236	18.6		157,173	23.6	

3.4.4 Samarra Site (Technical Assessment)

- Annual wind speed at 10m height = 5.31m/s, see Figure 3.9.
- Annual wind speed at 100m height = 6.2m/s.

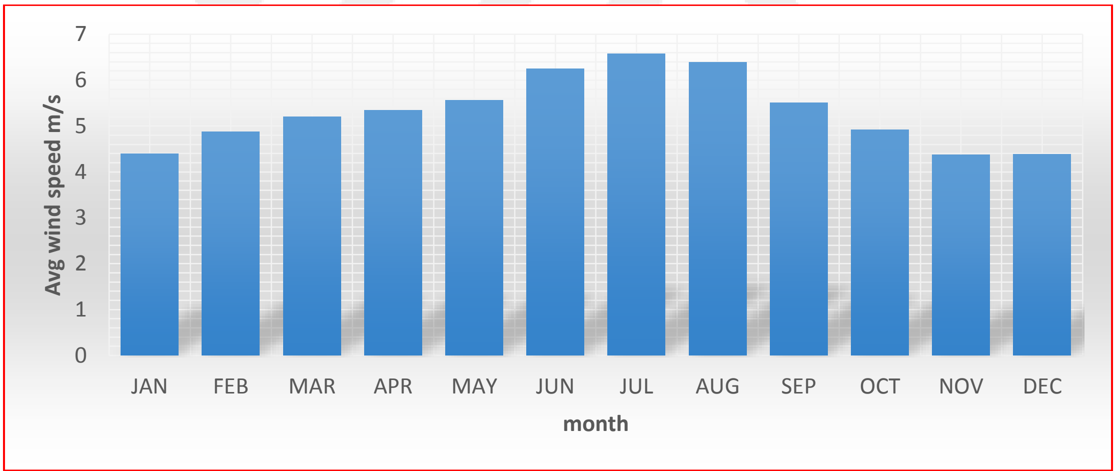

Figure 3.9: Monthly wind speed at the Samarra site at a height of 10 meters

Table 3.6 illustrates an analysis by the RETScreen software for the Samarra site to calculate the annual electricity exported to the grid and the capacity factor values for both wind projects (75 MW), using the Enercon-E82-E3-3000 kW wind turbines to start energy production from 88,394 MWh with C_F=13.5 at a 78-meter hub height, then rising gradually and finally reaching a value of 106,574 MWh with C_F=16.2 at a hub height of 138 m , while using the Enercon-E82-E2-2000 kW wind turbines the energy produced 118,028 MWh with C_F=17.7 at a 78-meter hub height, then rising gradually and finally reaching a value of 139,274 MWh with C_F=20.9 at a 138-meter hub height, as shown in Figure (3.10, 3.11, 3.12, 3.13).

Table 3.6: Annual electricity generation and capacity factors versus hub height for both types of wind turbine Enercon (3000, 2000) kW at the Samarra site

Hub height (m)	Enercon -E82-E3-3000KW			Enercon -E82-E2-2000KW		
	the annual electricity exported to grid (MWh)	capacity factor (%)	Number of turbines	the annual electricity exported to grid (MWh)	capacity factor (%)	Number of turbines
78	88,394	13.5	25	118,028	17.7	38
85	91,009	13.9		121,119	18.2	
98	95,471	14.5		126,324	19	
108	98,569	15		129,937	19.5	
138	106,574	16.2		139,274	20.9	

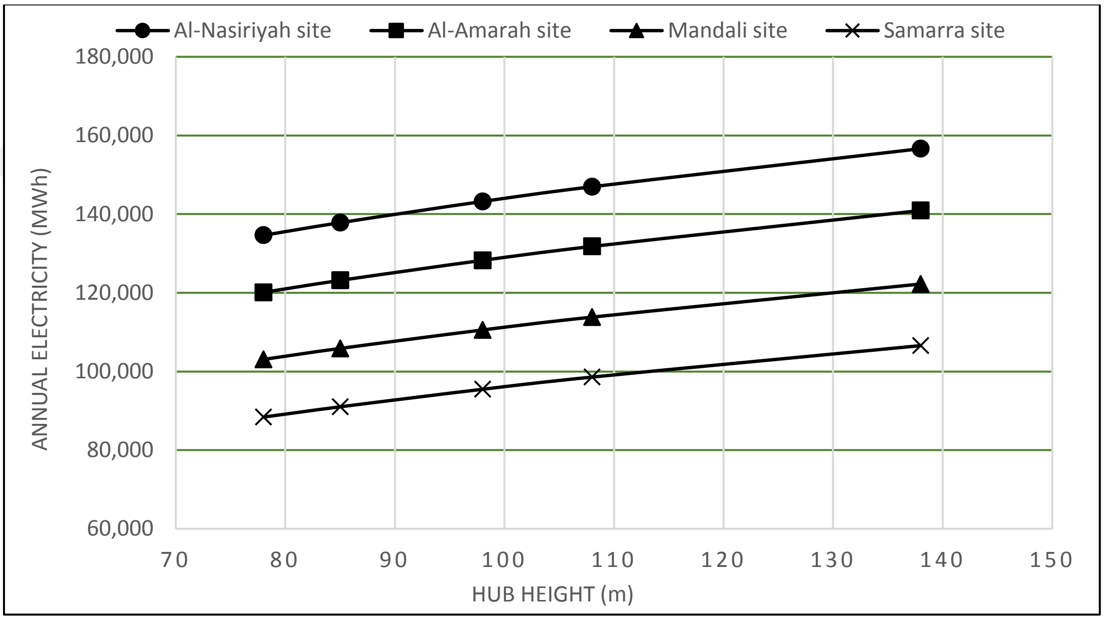

Figure 3.10: Annual electricity exported to the grid with hub heights for the Enercon 3000 kW wind project

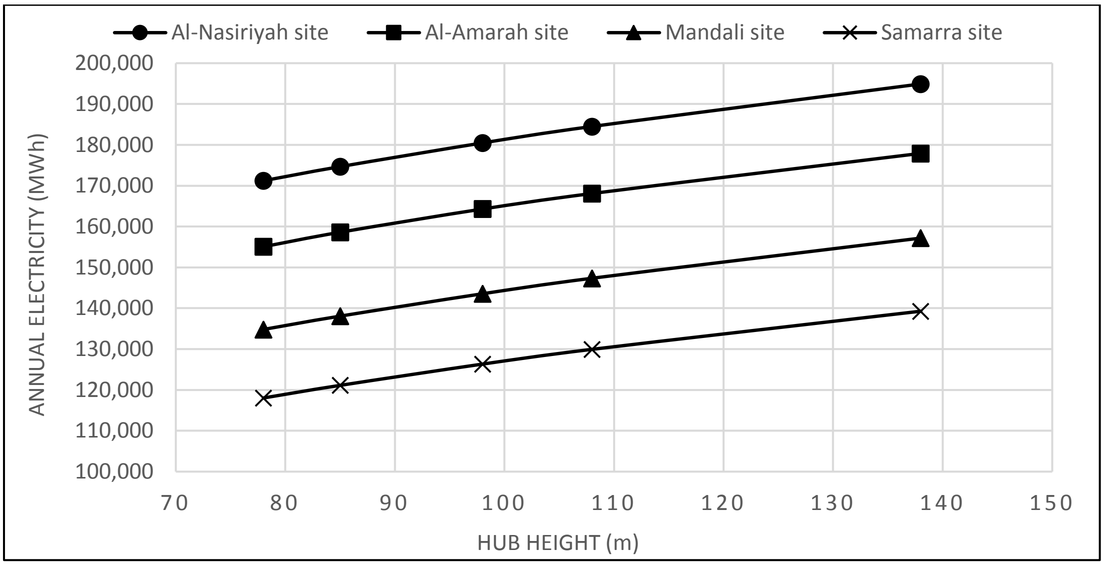

Figure 3.11: Annual electricity exported to the grid with hub heights for the Enercon 2000 kW wind project

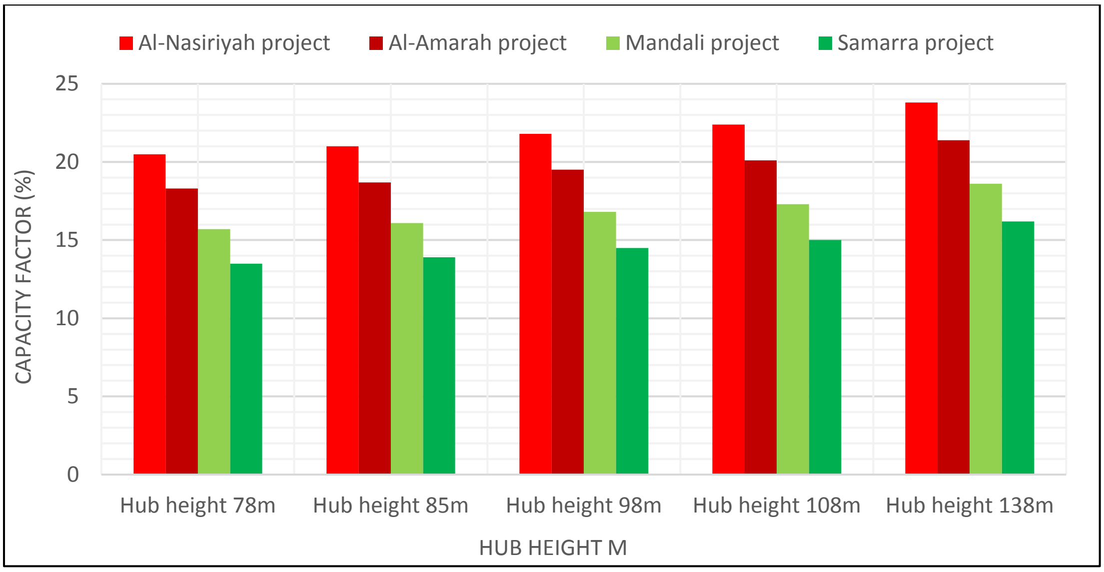

Figure 3.12: Capacity factors with hub heights for Enercon 3000 kW the wind project

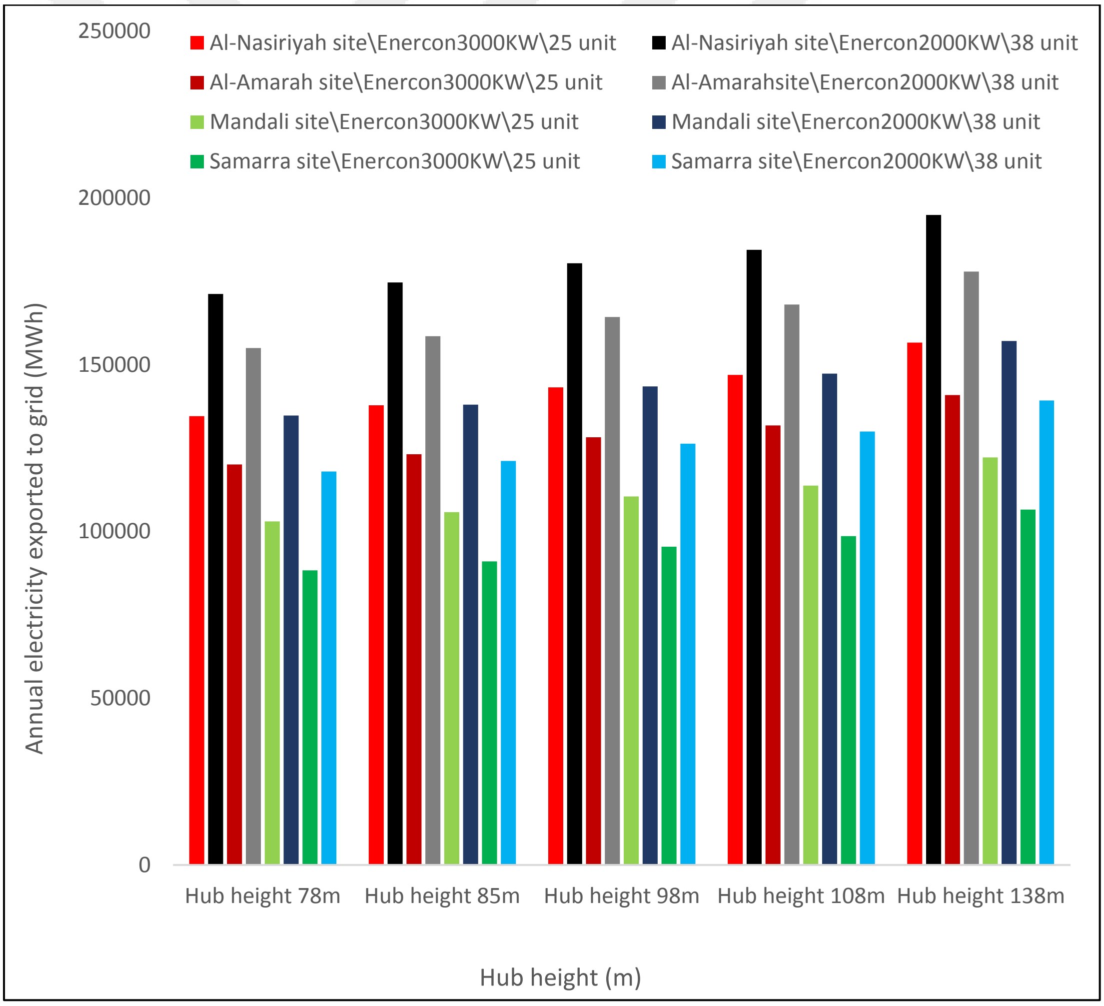

Figure 3.13: Annual electricity exported to the grid versus hub heights for the Enercon (3000, 2000) kW wind project

3.5 Farm Design

Wind turbines of various sizes are available commercially. Small machines are often used for standalone applications like domestic or small scale industrial needs. When we have to generate large quantities of power see table 3.7, several wind turbines are clubbed together and installed in clusters, forming a wind farm or wind park. There are several advantages in clustering wind machines. The installation, operation and maintenance of such plants are easier than managing several scattered units, delivering the same power. Moreover, the power transmission can be more efficient as the electricity may be transformed to a higher voltage.

Table 3.7: farm size

Wind farm size	Number of turbines
Small	1-3
Medium	3-20
Large	20-50
Very Large	50+

Optimum spacing is estimated to be 3-5 rotor diameters between towers and 5-9 between rows so that the wind stream passing through one turbine is restored before it interacts with the next turbine and wind farm design square arrays don’t make much sense but rectangular arrays with only a few long rows are better, these spacing may be further increased for better performance, but may be expensive as we require more land and other resources for farther spacing [51].

The wind farm is designed to the sites selected using Wind Ross, as illustrated in Fig. 3.15 to determine wind direction in sites and use Sam program to draw the farm shape.

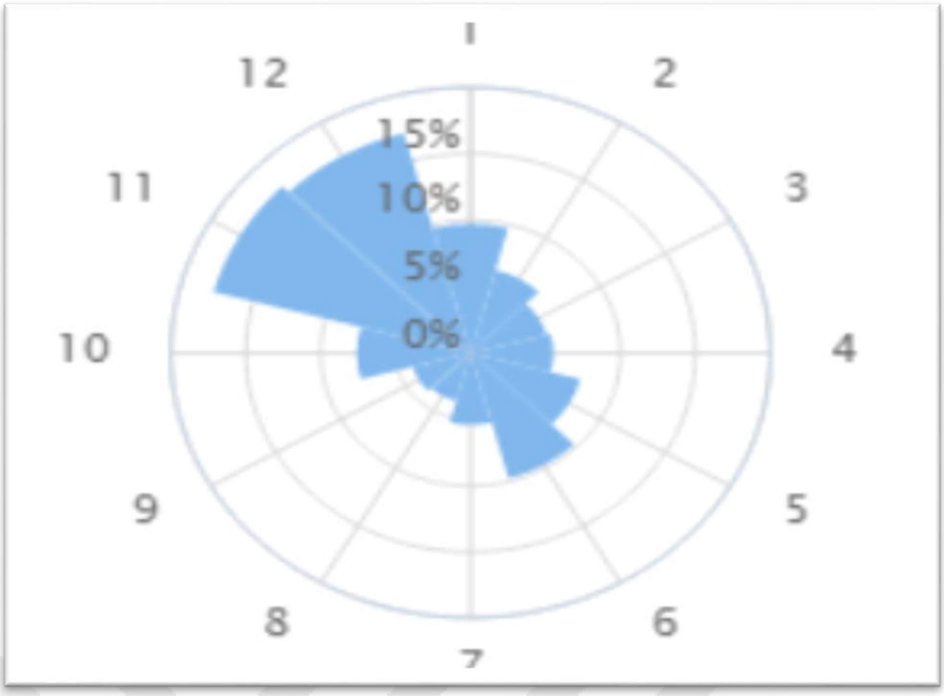

Figure 3.14: Wind Rose for all sites

3.6 Farm Design for the 75MW wind project with the Enercon-E82

Table 3.8 illustrates farm Design for the 75MW wind project with the Enercon-E82 (3000, 2000) kw.as shown in figure (3.15, 3.16)

Table 3.8: Table 3.8 illustrates farm Design for the 75MW wind project with the Enercon-E82 (3000, 2000) kw.

Item	Farm Design for the 75MW wind project with the Enercon-E82-E3-3000 kW	Design Farm for the 75MW wind project with the Enercon-E82-E2-2000 kW
NO. of unit	25	38
Turbines per row	8	10
Number of rows	3 (+1)	4(-2)
Turbine spacing	5 rotor diameter	5 rotor diameter
Row spacing	8 rotor diameter	8 rotor diameter
Offset of row	2.5 rotor diameter	2.5 rotor diameter
Farm shape	Rectangle	Rectangle
shape Dimensions	(X=3400m, Y=1500m)	(X=4300m, Y=2200m).
Total Area	5100000 m^2	9460000 m^2

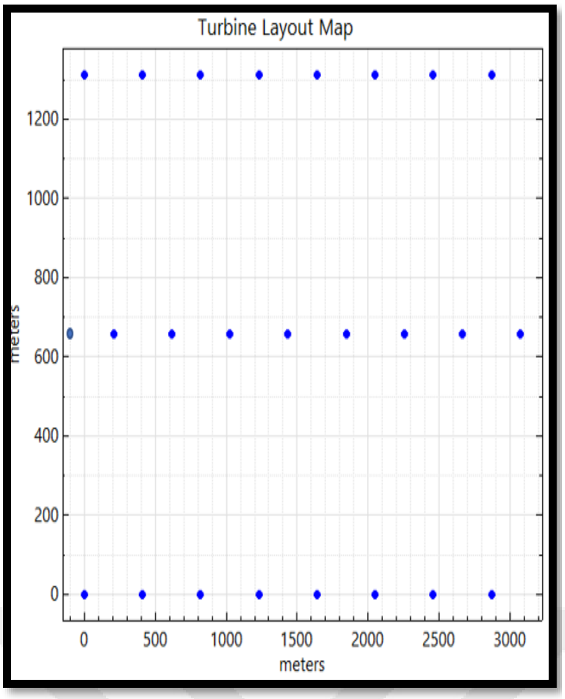

Figure 3.15: Design of 75MW wind farm using Enercon-E82-E2-3000 kW wind turbines

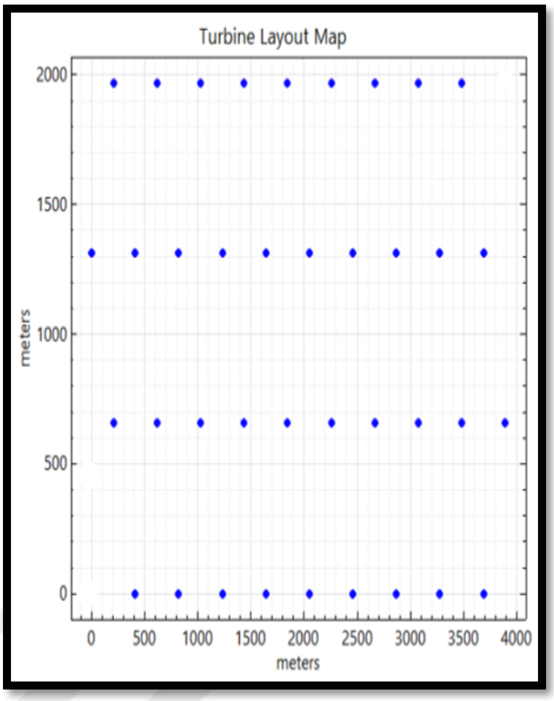

Figure 3.16: Design of 75MW wind farm using Enercon-E82-E2-2000 kW wind turbines

3.7 Calculate Net Annual Greenhouse Gases (GHG) Reduction Versus Hub Height for All Sites

This optional worksheet helps determine the annual reduction in the emission of greenhouse gases stemming from using the proposed technology in place of the base case technology. Through using the RETScreen software, the CO_2 emission reduction from the proposed energy model has been examined. The RETScreen is used to determine the annual GHG emission reduction for the project compared to conventional technology based cases and the results are presented in terms of tons of CO_2 per-year that will be equivalent to the emission reduction.

To account for greenhouse gases (GHG) for each site (Al-Nasiriyah, Al-Amarah, Mandali, and Samarra) of the following equation is employed:

Net annual GHG emission reduction = Base case GHG emission (tCO2) - Proposed case GHG emission (tCO_2)

Data taken for the GHG emissions worksheet:

- Fuel type: All type (Base case system).
- T&D losses (for developing countries): 16% (Base case system/ base line & Proposed case system/ wind power project) [48].

3.7.1 Al- Nasiriyah Site (GHG Emission)

Table 3.9 illustrates the calculations of the Net annual GHG emissions reduction of tCO_2 for projects using the Enercon E82-(3000, 2000) kW wind turbines from the RETScreen program at Al- Nasiriyah site and as the follow.

a- For the 75MW wind project using the Enercon-E82-E3-3000 kW/25-unit:

At a hub height of 78 m, the Net annual GHG emissions reduction will be 135,003 tCO_2, which is equivalent to 313,960 barrels of crude oil not consumed or the equivalent of 24,726 cars and light trucks not used. At a hub height of 85 m, it increases to 138,218 tCO_2, which is equivalent to 321,437 barrels of crude oil not consumed, or the equivalent of 25,315 cars and light trucks not used. At a hub height of 98 m, it increases to 143,627 tCO_2 and this equivalent 334,016 barrels crude oil not consumed or equivalent 26,305 cars and light trucks not used. At a hub height of 108 m, it then rises to 147,383 tCO_2, which is equivalent to 342,751 barrels of crude oil not consumed or the equivalent of 26,993 cars and light trucks not used. Finally, at a hub height of 138 m, it reaches 157,089 tCO_2, which is the equivalent of 365,323 barrels of crude oil not consumed, or the equivalent of 28,771 cars and light trucks not used, as shown in Figure 3.17.

b- For the 75MW wind project using the Enercon-E82-E2-2000 kW/38-unit:

At a hub height of 78 m, the Net annual GHG emissions reduction will be 171,705 tCO_2, which is equivalent to 399,314 barrels of crude oil not consumed, or the equivalent of 31,448 cars and light trucks not used. At a hub height of 85 m, it increases to 175,163 tCO_2, which is equivalent to 407,356 barrels of crude oil not consumed, or the equivalent of 32,081 cars and light trucks not used. At a hub height of 98 m, it increases to 180,983 tCO_2, which is equivalent to 420,891 barrels of crude oil not consumed, or the equivalent of 33,147 cars and light trucks not used. At a hub height of 108 m, it then rises to 185,023 tCO_2, which is equivalent to 430,286 barrels of crude oil not consumed, or the equivalent of 33,887 cars and light trucks not used. Finally, at a hub height of 138 m, it reaches 195,462 tCO_2, which is equivalent to 454,563 barrels of crude oil not consumed, or the equivalent of 35,799 cars and light trucks not used, as shown in Figure 3.17.

Table 3.9: Net annual GHG Emissions Reduction versus hub height for both types of wind turbines Enercon (3000, 2000) kW at the Al-Nasiriyah site

Hub height (m)	Enercon-E82-E3-3000KW wind turbine				Enercon-E82-E2-2000KW wind turbine			
	Net annual GHG emission reduction (tCO2)	Equivalent (barrels crude oil not consumed)	Equivalent (cars & light trucks not used)	No Of Tur.	Net annual GHG emission reduction (tCO2)	Equivalent (barrels crude oil not consumed	Equivalent (cars & light trucks not used)	No Of Tur.
78	135,003	313,960	24,726	25	171,705	399,314	31,448	38
85	138,218	321,437	25,315		175,163	407,356	32,081	
98	143,627	334,016	26,305		180,983	420,891	33,147	
108	147,383	342,751	26,993		185,023	430,286	33,887	
138	157,089	365,323	28,771		195,462	454,563	35,799	

3.7.2 Al-Amarah Site (GHG Emission)

Table 3.10 illustrates the calculations of the Net annual GHG emissions reduction of tCO_2 for the projects using the Enercon E82-(3000, 2000) kW wind turbines from the RETScreen program at the Al-Amarah site, where we note a gradual rise of the value of the GHG emissions reduction from the wind plant with an increased hub height, as shown in Figure 3.18.

Table 3.10: Net annual GHG Emissions Reduction versus hub height for both types of wind turbines Enercon (3000, 2000) kW at the Al-Amarah site

Hub height (m)	Enercon-E82-E3-3000KW wind turbine				Enercon-E82-E2-2000KW wind turbine			
	Net annual GHG emission reduction (tCO2)	Equivalent (barrels crude oil not consumed)	Equivalent (cars & light trucks not used)	No Of Tur	Net annual GHG emission reduction (tCO2)	Equivalent (barrels crude oil not consumed	Equivalent (cars & light trucks not used)	No Of Tur
78	120,458	280,135	22,062	25	155,505	361,640	28,481	38
85	123,502	287,214	22,619		159,056	369,898	29,131	
98	128,615	299,105	23,556		164,755	383,151	30,175	
108	132,160	307,349	24,205		168,568	392,019	30,873	
138	141,320	328,651	25,883		178,421	414,933	32,678	

3.7.3 Mandali Site (GHG Emission)

Table 3.11 illustrates the calculations of the Net annual GHG emissions reduction of tCO_2 for projects using the Enercon E82-(3000, 2000) kW wind turbines from the RETScreen program at Mandali site.

Table 3.11: Net annual GHG Emissions Reduction versus hub height for both types of wind turbines Enercon (3000, 2000) kW at the Mandali site

Hub height (m)	Enercon-E82-E3-3000KW wind turbine				Enercon-E82-E2-2000KW wind turbine			
	Net annual GHG emission reduction (tCO2)	Equivalent (barrels crude oil not consumed)	Equivalent (cars & light trucks not used)	No Of Tur	Net annual GHG emission reduction (tCO2)	Equivalent (barrels crude oil not consumed	Equivalent (cars & light trucks not used)	No Of Tur
78	103,357	240,365	18,930	25	135,194	314,405	24,761	38
85	106,156	246,874	19,442		138,458	321,995	25,359	
98	110,865	257,826	20,305		143,951	334,770	26,365	
108	114,134	265,428	20,904		147,764	343,637	27,063	
138	122,583	285,077	22,451		157,619	366,556	28,868	

3.7.4 Samarra Site (GHG Emission)

Table 3.12 illustrates the analysis from the RETScreen software at Samarra site to calculate the Net annual GHG emission reduction of tCO_2 for both wind projects (75 MW). When we use the Enercon-E82-E3-3000 kW wind turbines, the value will be 88,644 tCO_2 (Net annual GHG emission reduction) and this value is equivalent to 206,149 barrels of crude oil not consumed or the equivalent of 16,235 cars and light trucks not used at a hub height of 78 m. Then it rises gradually and finally reaches a value of 106,876 tCO_2 (Net annual GHG emissions reduction) and this value is the equivalent of 248,549 barrels crude oil not consumed or the equivalent of 19,574 cars and light trucks not used at a hub height of 138 m. While we use the Enercon-E82-E2-2000 kW wind turbines, the project will give a value of 118,363 tCO_2 (Net annual GHG emissions reduction) and this value is the equivalent of 275,263 barrels of crude oil not consumed or the equivalent of 21,678 cars and light trucks not used at a hub height of 78 m. Then it rises gradually and finally reaches a value of 139,669 tCO_2 (Net annual GHG emission reduction) and this value is the equivalent of 324,812 barrels crude oil not consumed or the equivalent of 25,580 cars and light trucks not used at a hub height of 138 m, as shown in Figure 3.17 below.

Table 3-12: Net annual GHG Emissions Reduction versus hub height for both types of wind turbines Enercon (3000, 2000) kW at the Samarra site

Hub height (m)	Enercon-E82-E3-3000KW wind turbine				Enercon-E82-E2-2000KW wind turbine			
	Net annual GHG emission reduction (tCO2)	Equivalent (barrels crude oil not consumed)	Equivalent (cars & light trucks not used)	No Of Tur	Net annual GHG emission reduction (tCO2)	Equivalent (barrels crude oil not consumed	Equivalent (cars & light trucks not used)	No Of Tur
78	88,644	206,149	16,235	25	118,363	275,263	21,678	38
85	91,267	212,249	16,715		121,463	282,472	22,246	
98	95,742	222,656	17,535		126,682	294,609	23,202	
108	98,849	229,881	18,104		130,306	303,037	23,866	
138	106,876	248,549	19,574		139,669	324,812	25,580	

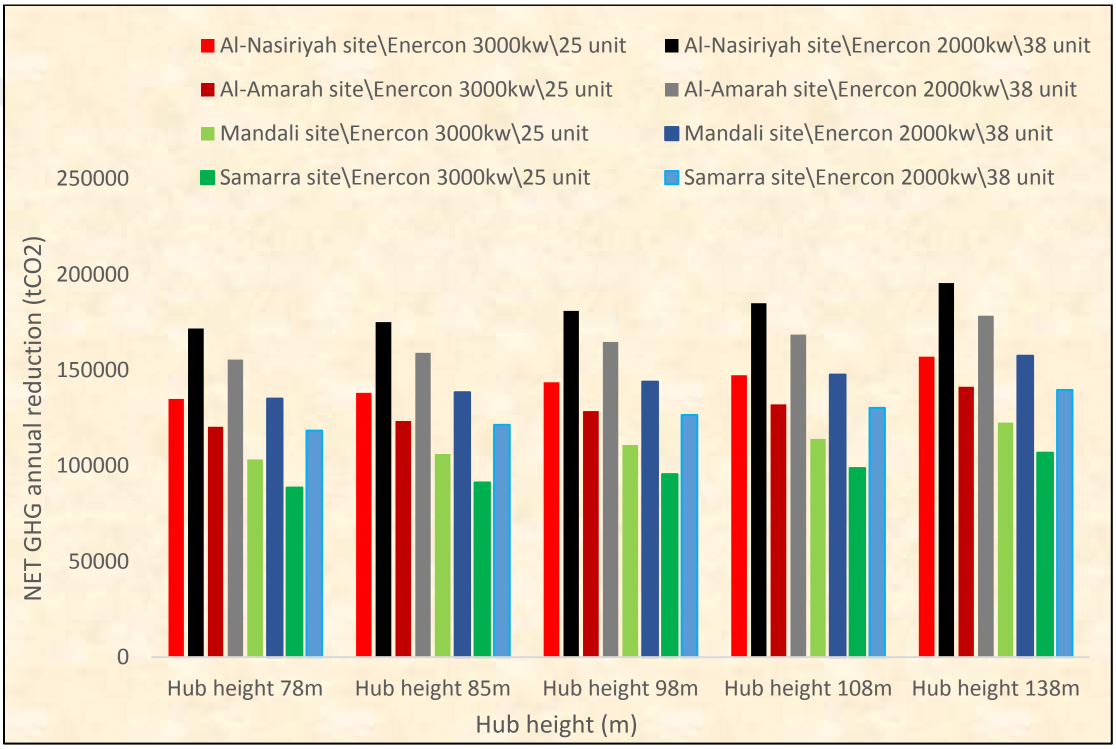

Figure 3.17: Net annual GHG emission reduction of tCO2 versus hub height for all Enercon (3000, 2000) kW projects at all sites

3.8 TECHNICAL SUMMARY

1- The Enercon wind turbine works at a cut-in speed 2.5 m/s to produce electricity.
2- We selected the Enercon wind turbine at a hub height of 138m for cost and financial analysis in chapter 4 as the 138-meter hub height had the best electricity output versus other hub heights.
3- The best value of the greenhouse gases was achieved using an Enercon wind turbine with a hub height of 138m, with benefits of financial revenues from greenhouse gasses reduction impacting on the tariffs presented in the chapter 4.

CHAPTER FOUR

COST AND FINANCIAL ANALYSIS

4.1 Cost Analysis

As part of the RETScreen Clean Energy Project Analysis Software, the Cost Analysis worksheet is used to help the user estimate costs associated with the proposed case. These costs are addressed from the initial, or investment, cost standpoint and from the annual, or recurring, cost standpoint. The most cost effective installations of renewable, cogeneration or energy-efficient technologies normally occur in new construction. The second most cost effective installation is likely for retrofit situations when there are plans to either repair or upgrade an existing system or equipment. However, it is certainly possible that high cooling, heating and/or electricity costs, or financial incentives could make the proposed case financially attractive [48].

4.1.1 Feasibility Study

Once a potential cost-effective proposed case project has been identified through the RETScreen pre-feasibility analysis process, a more detailed feasibility analysis study is often required. This is particularly the case for large projects. Feasibility studies typically include such items as a site investigation, a resource assessment, an environmental assessment, a preliminary project design, a detailed cost estimate, a GHG baseline study and monitoring plan (MP) and a final report. Feasibility study project management and travel costs are also normally incurred.

4.1.2 Development

Once the proposed case project has been identified through the feasibility study to be desirable to implement, project development activities follow. For some projects, the feasibility study, development and engineering activities might proceed in parallel, depending on the risk and return acceptable to the project proponent, it includes (Contract negotiations, Permits & approvals, Site survey & land rights, GHG validation & registration, Project financing, Legal & accounting, Project management, Travel & accommodation)

4.1.3 Engineering

The engineering phase includes costs for the proposed case project site & building design, mechanical design, electrical design, civil design, tenders & contracting, and construction supervision

4.1.4 Power System

as defined here, includes the base load, intermediate load, peak load and/or back-up power equipment, and the associated road construction, transmission line, substation and power-related energy efficiency measures costs.

4.1.5 Specific Project Costs

includes (Wind turbine foundation, Wind turbine erection, Building & yard construction, Spare parts, Transportation, Training & commissioning).

4.1.6 Contingencies

The allowance made for contingency costs depends on the level of accuracy of the cost estimates. Contingencies are estimated based on a user-selected percentage of the sub-total of all project costs excluding interest during construction. Note that contingencies are incremental in the sense that they are derived from project costs including any credits.

4.1.7 Interest During Construction

Interest during construction (short-term construction financing) will vary depending on the duration of construction and the cost of money. The user enters the interest rate (%) and the length of construction in months (which represents the length of time between building or infrastructure construction, delivery of the equipment (one of the most important cost items) and commissioning of the system) [48].

Table 4.1: Total initial costs and O&M Annual costs

Item	Cost for Wind project Enercon-3000 KW/25-unit ($USD)	Cost for Wind project Enercon-2000 KW/38 unit ($USD)
Feasibility study	1,000,000	2,500,000
Development	1,085,000	2,500,000
Engineering	2,700,000	6,500,000
Power system	79,702,000	108,670,000
Specific project costs	9,760,000	18,855,000
Contingencies	9,424,700	13,902,500
Interest during construction	1,555,076	2,293,913
Total initial costs	105,226,776	155,221,413
O&M Annual costs	3,187,500	4,845,000

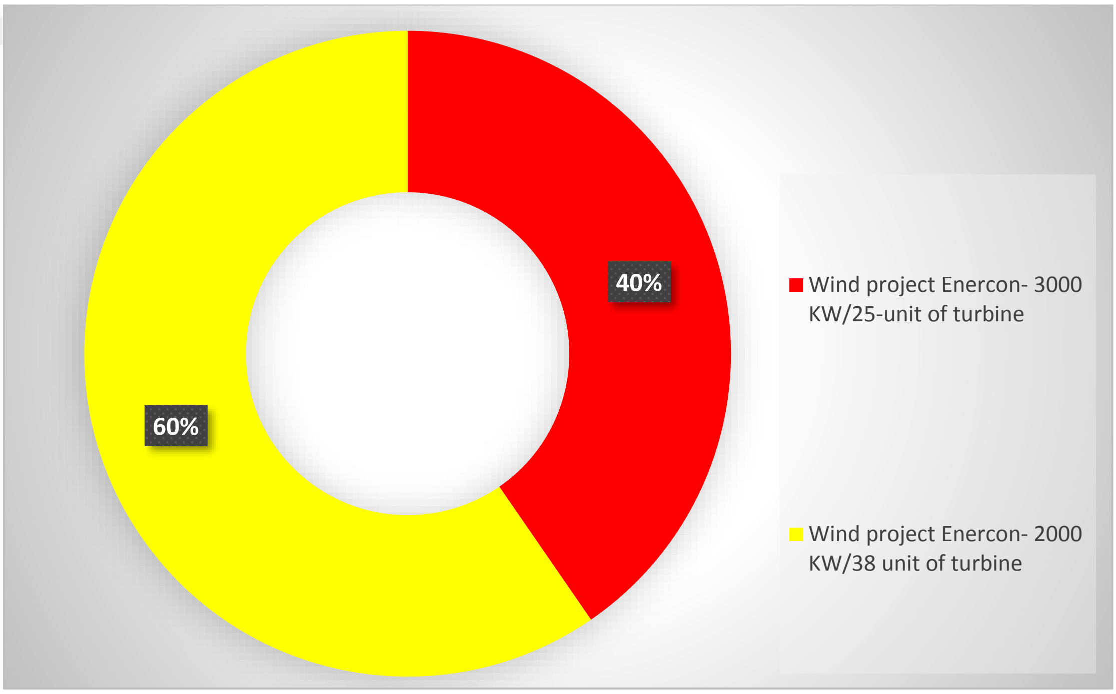

Figure 4.1: Total initial costs & O&M Annual costs for both types of wind turbine Enercon

4.2 Financial Analysis:

In this worksheet, the user specifies financial parameters related to the avoided cost of energy, production credits, GHG emission reduction credits, Incentives and grants, inflation, discount rate, debt, and taxes. From this, RETScreen calculates a variety of financial indicators to evaluate the viability of the project (Simple payback (SPB), Net present value (NPV), Annual life cycle savings(ALCS)). A cumulative cash flow graph is also included in the financial summary worksheet [48].

4.2.1 Cash Flows

The calculation of cash flows keeps track, on a yearly basis, of all expenses (outflows) and incomes (inflows) generated by the clean energy project.

- **Cash Outflow**

$$C_{out;n} = C_{O\&M}(1 + r_i)^n + C_{fuel}(1 + r_e)^n + D + C_{per}(1 + r_i)^n$$

where n is the year, $C_{O\&M}$is the yearly operation and maintenance costs incurred by the clean energy project, r_i is the inflation rate, C_{fuel} is the annual cost of fuel or electricity, $r_e$is the energy cost escalation rate, D is the annual debt payment, and $C_{per}$is the periodic costs or credits incurred by the system

- **Cash Inflow**

$$C_{in;n} = C_{ener}(1 + r_e)^n + C_{capa}(1 + r_i)^n + C_{RE}(1 + r_{RE})^n + C_{GHG}(1 + r_{GHG})^n$$

where n is the year, $C_{ener}$is the annual energy savings or income, $C_{capa}$is the annual capacity savings or income, C_{RE} is the annual renewable energy (RE) production credit income, $r_{RE}$the RE credit escalation rate,C_{GHG} is the GHG reduction income, $r_{GHG}$is the GHG credit escalation rate. For the last year, the end-of-project life credit, incremented by inflation [48].

4.2.2 Simple Payback (SPB)

The simple payback (SPB) is the number of years it takes for the cash flow (excluding debt payments) to equal the total investment (which is equal to the sum of the debt and equity)

- The time it takes for the project to generate money to pay for itself.
- The payback period is the number of years required to recover the cash outflow invested in the project.
- It terms of projects ranking, it gives highest ranking to the project with the shortest payback period.

$$SP = \frac{C - IG}{(C_{ener} + C_{capa} + C_{RE} + C_{GHG}) - (C_{O\&M} + C_{fuel})}$$

where n is the year, C is the total initial cost of the project, C_{ener} is the annual energy savings or income, C_{capa} is the annual capacity savings or income, C_{RE} is the annual renewable energy (RE) production credit income, C_{GHG} is the GHG reduction income, C_{fuel} is the annual cost of fuel or electricity, incentives and grants IG [48].

4.2.3 Net Present Value (NPV)

The Net present value (NPV) of a project is the value of all future cash flows, discounted at the discount rate, in today's currency.

- NPV realistically predicts future cashflows.
- NPV discounts future cashflows at an appropriate industry discount rate, the appropriate discount rate is the projects opportunity cost of capital.
- NPV is the sum of all discounted cashflows.
- IF NPV> 0 (positive), the project can be accepted, and the greater the NPV, the better the project's financial benefits.

Net present value = present value of cash inflows – present value of cash outflows.

$$NPV = \sum_{n=0}^{N} \frac{C_n^-}{(1+r)^n}$$

where r is the discount rate and C_n^- is the after-tax cash flow in year n, where N is the project life in years [48].

4.2.4 Annual Life Cycle Savings (ALCS)

The Annual Life Cycle Savings (ALCS) is the liveliest nominal yearly savings having exactly the same life and Net present value as the project [48]. It is calculated using the following formula:

$$ALCS = \frac{NPV}{\frac{1}{r}\left[1 - \frac{1}{(1+r)^N}\right]}$$

It can be considered the following situations to calculate the financial functions [Simple payback (SPB), Net present value (NPV), Annual life cycle savings (ALCS)]

<u>Situation 1</u>: Effect of Grants on Simple payback period (SPB), Net present value (NPV) and Annual Life Cycle Savings (ALCS) from project life under different tariffs\GHG income ($0/t$CO_2$).

<u>Situation 2</u>: Impact of GHG income on Simple payback period (SPB), Net present value (NPV) and Annual Life Cycle Savings (ALCS) under different tariffs\ Grant 1 = (USD$0)

4.3 Situation 1: Evaluation of Projects by Calculating [(SPB), (NPV), (ALCS)] Versus Tariffs by Effect of The Grants for All Sites\GHG income ($0/t$CO_2$)

We assume that grants from foreign international organizations are rated as follows:

- Grant 1 = 0% × total initial costs from 75MW wind project with the Enercon-E82-E3-3000 kW = USD$0
- Grant 2 = 30% × total initial costs from 75MW wind project with the Enercon-E82-E3-3000 kW = USD$31.57MM.
- Grant 3 = 60% × total initial costs from 75MW wind project with the Enercon-E82-E3-3000 kW = USD$63.14MM.

Where $MM USD is in millions of US dollars.

4.4 Al-Nasiriyah Site (Financial / Grant)

4.4.1 Evaluation of Projects by Calculating a Simple Payback Period (SPB) Versus Tariffs by the Effect of The Grants

Table 4.2 illustrates the calculation of the Simple Payback Period (SPB) versus Tariffs showing effects the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines using the RETScreen program at the Al-Nasiriyah site.

a- For the 75MW wind project with the Enercon-E82-E3-3000 kW/25-unit:

- At a tariff of $40/MWh, the simple payback (SPB) becomes 34.2 years with grant 1, decreasing to 23.9 years with grant 2 and reaches 13.7 years with grant 3.
- At a tariff of $80/MWh, the simple payback becomes 11.5 years with grant 1, decreasing to 7.9 years with grant 2 and reaches 4.5 years with grant 3.
- At a tariff of $140/MWh, the simple payback becomes 5.6 years with grant 1, decreasing to 3.9 years with grant 2 and reaches 2.2 years with grant 3.
- At a tariff of $300/MWh, the simple payback becomes 2.4 years with grant 1, decreasing to 1.7 years with grant 2 and reaching 1.0 year with grant 3, as shown in Figure 4.2.

b- For the 75MW wind project with the Enercon-E82-E2-2000 kW/38 unit:

- At a tariff of $40/MWh, the simple payback (SPB) becomes 52.6 years with grant 1, decreasing to 41.9 years with grant 2 and reaching 31.2 years with grant 3.
- At a tariff of $80/MWh, the simple payback (SPB) becomes 14.4 years with grant 1, decreasing to 11.5 years with grant 2 and reaching 8.6 years with grant 3.
- At a tariff of $140/MWh, the simple payback becomes 6.9 years with grant 1, decreasing to 5.5 years with grant 2 and reaching 4.1 years with grant 3.
- At a tariff of $300/MWh, the simple payback becomes 2.9 years with grant 1, decreasing to 2.3 years with grant 2 and reaching 1.7 years with grant 3, as shown in Figure 4.3.

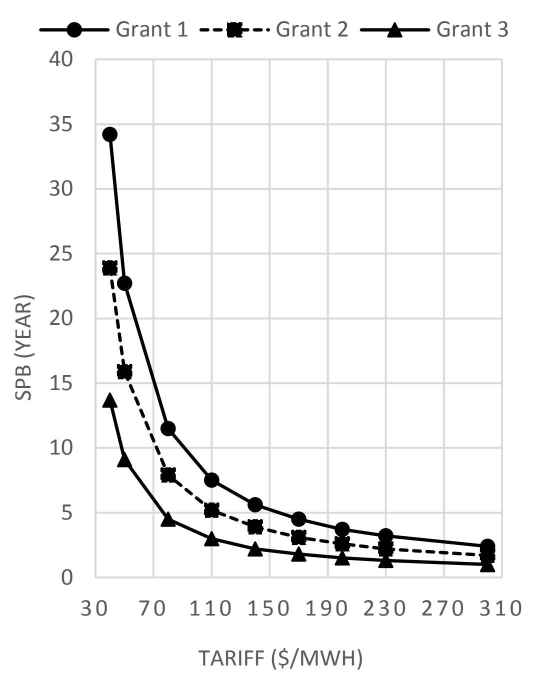

Figure 4.2: SPB versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW at the Al-Nasiriyah site\GHG income ($0/tCO₂)

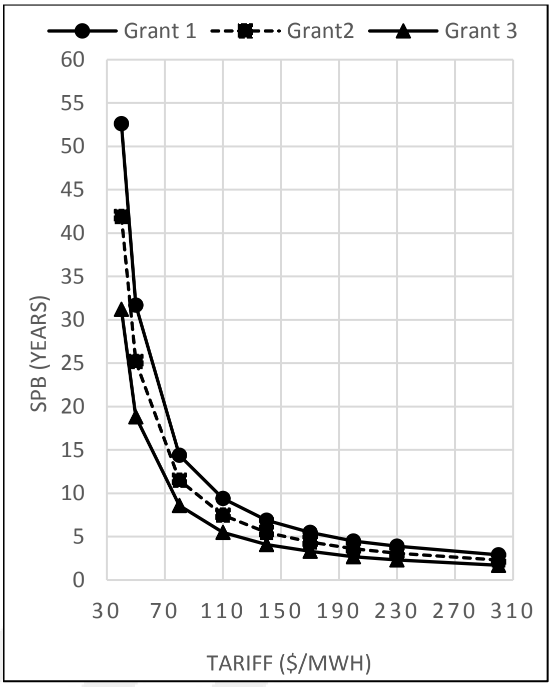

Figure 4.3: SPB versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW/ at the Al-Nasiriyah site\GHG income ($0/tCO₂)

Table 4.2: SPB versus Tariffs showing the effects on grants for the 75MW wind project at the Al-Nasiriyah site

Tariff ($/MWh)	SPB(years)					
	Wind project Enercon- 3000 KW/25 unit turbine			Wind project Enercon- 2000 KW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	34.2	23.9	13.7	52.6	41.9	31.2
50	22.7	15.9	9.1	31.7	25.2	18.8
80	11.5	7.9	4.5	14.4	11.5	8.6
110	7.5	5.2	3	9.4	7.5	5.5
140	5.6	3.9	2.2	6.9	5.5	4.1
170	4.5	3.1	1.8	5.5	4.4	3.3
200	3.7	2.6	1.5	4.5	3.6	2.7
230	3.2	2.2	1.3	3.9	3.1	2.3
300	2.4	1.7	1	2.9	2.3	1.7

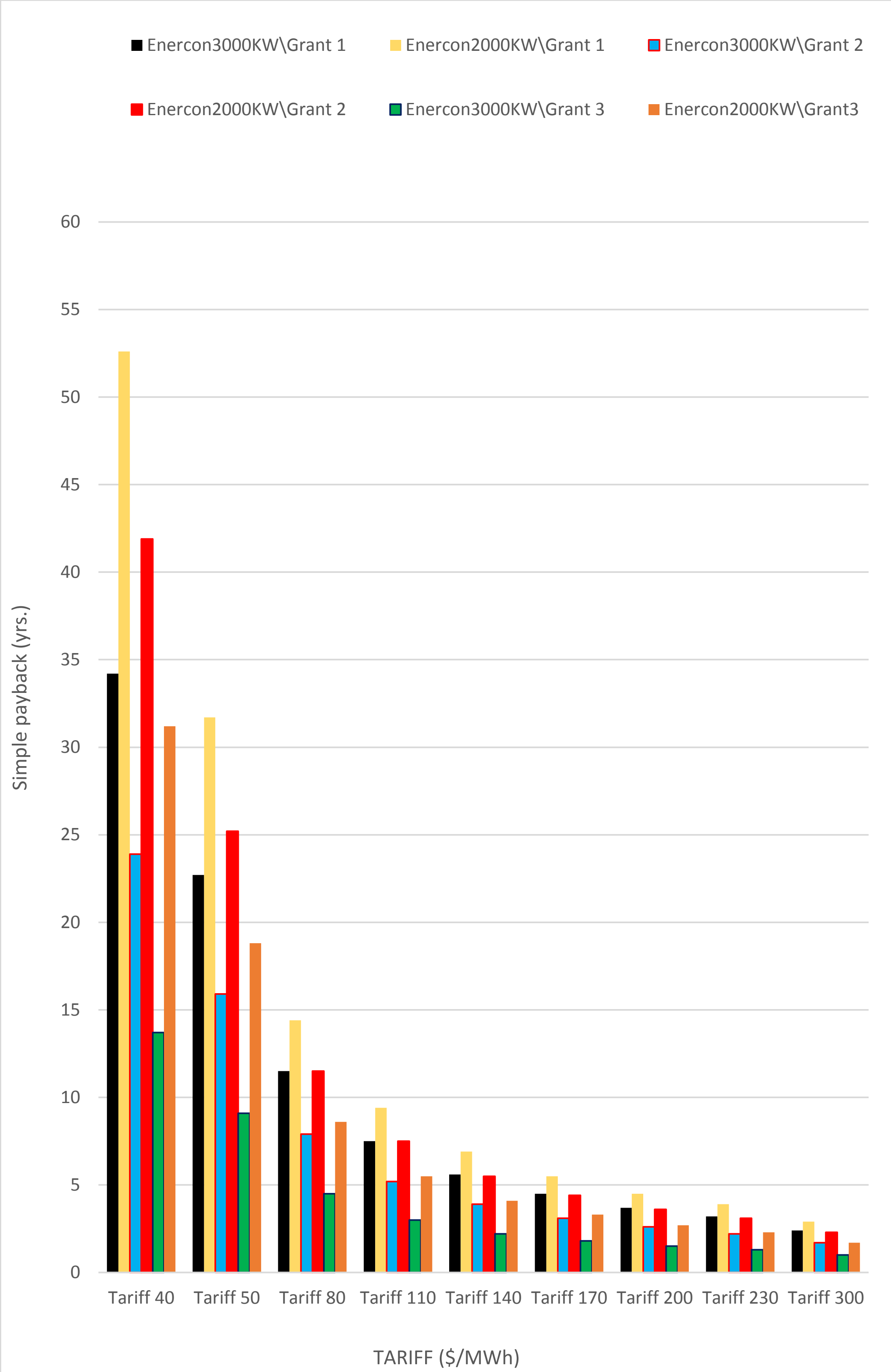

Figure 4.4: Simple Payback Period with tariffs with the effect on all grants for all Enercon (3000, 2000) kW projects at the Al-Nasiriyah site\GHG income ($0/tCO$_2$)

4.4.2 Evaluation of Projects by Calculating Net Present Value (NPV) Versus Tariffs by the Effect of The Grants

Table 4.3 illustrates the calculations of the Net Present Value (NPV) versus Tariffs showing effects the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Nasiriyah site.

a- For the 75MW wind project with the Enercon-E82-E3-3000 kW/25 unit:

- At a tariff of $40/MWh, the Net Present Value (NPV) becomes -$86,190,270 with grant 1, rising to -$54,622,237 with grant 2 and reaching -$23,054,204 with grant 3.
- At a tariff of $80/MWh, the Net Present Value (NPV) becomes -$29,315,623 with grant 1, increasing to $2,252,410 with grant 2 and reaching $33,820,443 with grant 3.
- At a tariff of $140/MWh, the NPV becomes $55,996,347 with grant 1, increasing to $87,564,380 with grant 2 and reaching $119,132,413 with grant 3.
- At a tariff of $300/MWh, the NPV becomes $283,494,934 with grant 1, increasing to $315,062,967 with grant 2 and reaching $346,631,000 with grant 3, as shown in Figure 4.5.

b- For the 75MW wind project with the Enercon-E82-E2-2000 kW/38 unit:

- At a tariff of $40/MWh, the Net Present Value (NPV) becomes -$141,967,355 with grant 1, rising to -$110,399,322 with grant 2 and reaching -$78,831,289 with grant 3.
- At a tariff of $80/MWh, the NPV becomes -$71,199,323 with grant 1, rising to -$39,631,290 with grant 2 and reaching -$8,063,257 with grant 3.
- At a tariff of $140/MWh, the NPV becomes $34,952,725 with grant 1, increasing to $66,520,758 with grant 2 and reaching $98,088,791 with grant 3.
- At a tariff of $300/MWh, the NPV becomes $318,024,854 with grant 1, increasing to $349,592,887 with grant 2 and reaching $381,160,920 with grant 3, as shown in Figure 4.6.

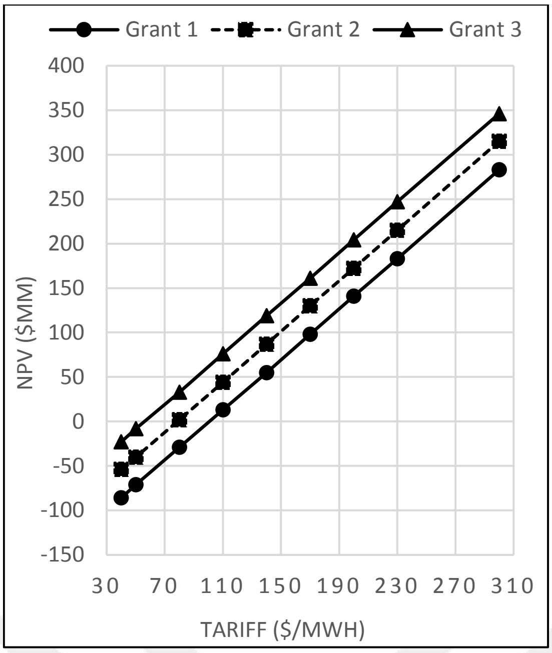

Figure 4.5: NPV versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Nasiriyah site\GHG income ($0/tCO$_2$)

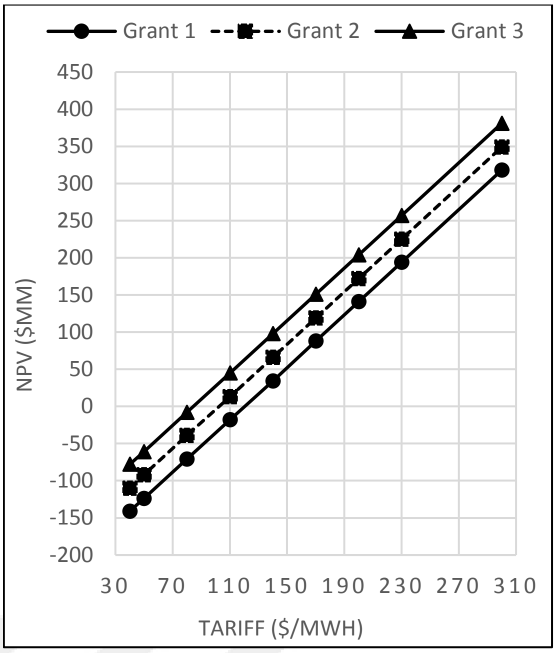

Figure 4.6: NPV versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Nasiriyah site\GHG income ($0/tCO$_2$)

Table 4.3: NPV versus Tariffs showing the effects on grants for the 75MW wind project at the Al-Nasiriyah site

Tariff ($/MWh)	NPV ($)					
	Wind project Enercon- 3000 KW/25-unit turbine			Wind project Enercon- 2000 KW/38-unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	-86,190,270	-54,622,237	-23,054,204	-141,967,355	-110,399,322	-78,831,289
50	-71,971,608	-40,403,575	-8,835,542	-124,275,347	-92,707,314	-61,139,281
80	-29,315,623	2,252,410	33,820,443	-71,199,323	-39,631,290	-8,063,257
110	13,340,362	44,908,395	76,476,428	-18,123,299	13,444,734	45,012,767
140	55,996,347	87,564,380	119,132,413	34,952,725	66,520,758	98,088,791
170	98,652,332	130,220,365	161,788,398	88,028,750	119,596,783	151,164,816
200	141,308,317	172,876,350	204,444,383	141,104,774	172,672,807	204,240,840
230	183,964,302	215,532,335	247,100,368	194,180,798	225,748,831	257,316,864
300	283,494,934	315,062,967	346,631,000	318,024,854	349,592,887	381,160,920

4.4.3 Evaluation of projects by calculating Annual Life Cycle Savings (ALCS) Versus Tariffs by the Effect of The Grants

Table 4.4 illustrates the calculations of the Annual Life Cycle Savings (ALCS) versus Tariffs showing effects the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Nasiriyah site.

a- For the 75MW wind project with the Enercon-E82-E3-3000 kW/25 unit:

- At a tariff of $40/MWh, the Annual Life Cycle Savings (ALCS) becomes -$9,495,416/year with grant 1, rising to -$6,017,627/year with grant 2 and reaching -$2,539,837/year with grant 3.
- At a tariff of $80/MWh, the ALCS becomes -$3,229,646/year with grant 1, increasing to $248,144/year with grant 2 and reaching $3,725,933/year with grant 3.
- At a tariff of $140/MWh, the ALCS becomes $6,169,010/year with grant 1, increasing to $9,646,799/year with grant 2 and reaching $13,124,588/year with grant 3.
- At a tariff of $300/MWh, the ALCS becomes $31,232,090/year with grant 1, increasing to $34,709,880/year with grant 2 and reaching $38,187,669/year with grant 3, as shown in Figure 4.7.

b- For the 75MW wind project with the Enercon-E82-E2-2000 kW/38 unit:

- At a tariff of $40/MWh, the Annual Life Cycle Savings (ALCS) becomes -$15,640,270/year with grant 1, rising to -$12,162,480/year with grant 2 and reaching -$8,684,691/year with grant 3.
- At a tariff of $80/MWh, the ALCS becomes -$7,843,892/year with grant 1, rising to -$4,366,103/year with grant 2 and reaching -$888,313/year with grant 3.
- At a tariff of $140/MWh, the ALCS becomes $3,850,674/year with grant 1, increasing to $7,328,464/year with grant 2 and reaching $10,806,253/year with grant 3.
- At a tariff of $300/MWh, the ALCS becomes $35,036,185/year with grant 1, increasing to $38,513,974/year with grant 2 and reaching $41,991,764/year with grant 3, as shown in Figure 4.8.

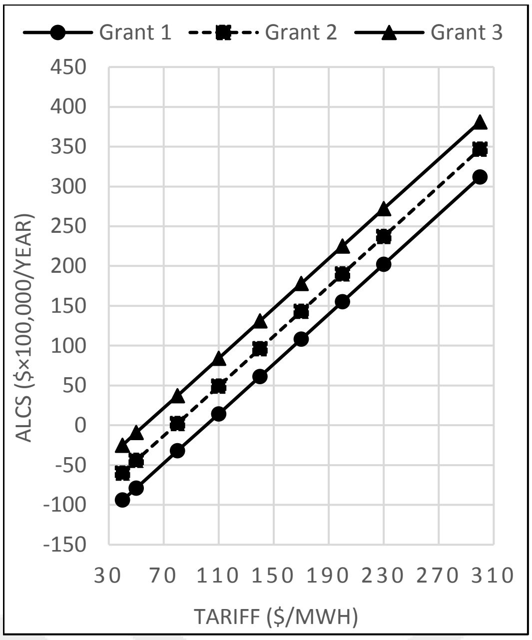

Figure 4.7: ALCS versus Tariffs showing the effects on grants for the 75MWwind project with the Enercon-E82-E3-3000 kW turbine at the Al-Nasiriyah site\GHG income ($0/t$CO_2$)

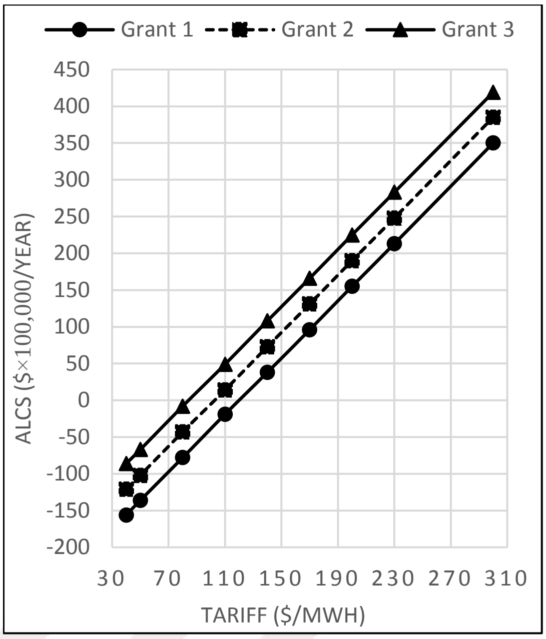

Figure 4.8: ALCS versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Nasiriyah site\GHG income ($0/t$CO_2$)

Table 4.4: ALCS versus Tariffs showing the effects on grants for the 75MW wind project at the Al-Nasiriyah site

Tariff ($/MWh)	ALCS ($/year)					
	Wind project Enercon- 3000 KW/25 unit of turbine			Wind project Enercon- 2000 KW/38 unit of turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	-9,495,416	-6,017,627	-2,539,837	-15,640,270	-12,162,480	-8,684,691
50	-7,928,973	-4,451,184	-973,395	-13,691,175	-10,213,386	-6,735,597
80	-3,229,646	248,144	3,725,933	-7,843,892	-4,366,103	-888,313
110	1,469,682	4,947,471	8,425,261	-1,996,609	1,481,180	4,958,970
140	6,169,010	9,646,799	13,124,588	3,850,674	7,328,464	10,806,253
170	10,868,337	14,346,127	17,823,916	9,697,958	13,175,747	16,653,536
200	15,567,665	19,045,454	22,523,244	15,545,241	19,023,030	22,500,820
230	20,266,993	23,744,782	27,222,571	21,392,524	24,870,313	28,348,103
300	31,232,090	34,709,880	38,187,669	35,036,185	38,513,974	41,991,764

4.5 Al-Amarah Site (Financial / Grant)

4.5.1 Evaluation of Projects by Calculating a Simple Payback Period (SPB) Versus Tariffs by the Effect of The Grants

Table 4.5 illustrates the calculations of the SPB versus Tariffs showing effects the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Amarah site, where we note a drop in the SPB with an increase in the tariff, as shown in Figure 4.9 and Fig. 4.10.

Table 4.5: SPB versus Tariffs showing the effects on grants for the 75MW wind project at Al-Amarah site

Tariff ($/MWh)	SPB(yrs.)					
	Wind project Enercon- 3000 KW/25 unit			Wind project Enercon- 2000 KW/38 unit		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	43	30.1	17.2	68.3	54.4	40.5
50	27.3	19.1	10.9	38.3	30.5	22.7
80	13	9.1	5.2	16.5	13.2	9.8
110	8.5	6	3.4	10.5	8.4	6.3
140	6.4	4.5	2.5	7.7	6.2	4.6
170	5.1	3.5	2	6.1	4.9	3.6
200	4.2	2.9	1.7	5	4	3
230	3.6	2.5	1.4	4.3	3.4	2.6
300	2.7	1.9	1.1	3.2	2.5	1.9

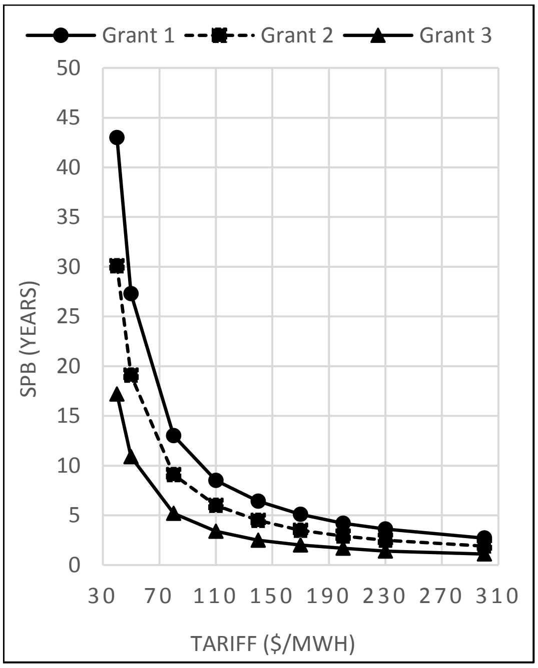

Figure 4.9: SPB versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Amarah site\GHG income ($0/tCO$_2$)

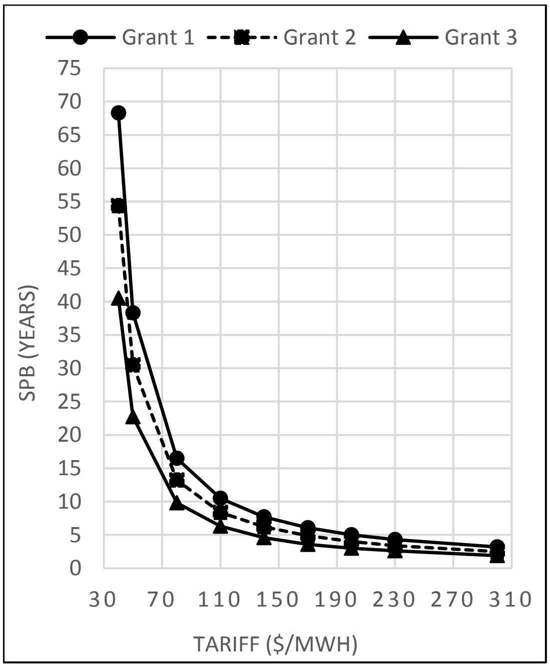

Figure 4.10: SPB versus Tariffs showing the effects on grants for the 75-MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Amarah site\GHG income ($0/tCO$_2$)

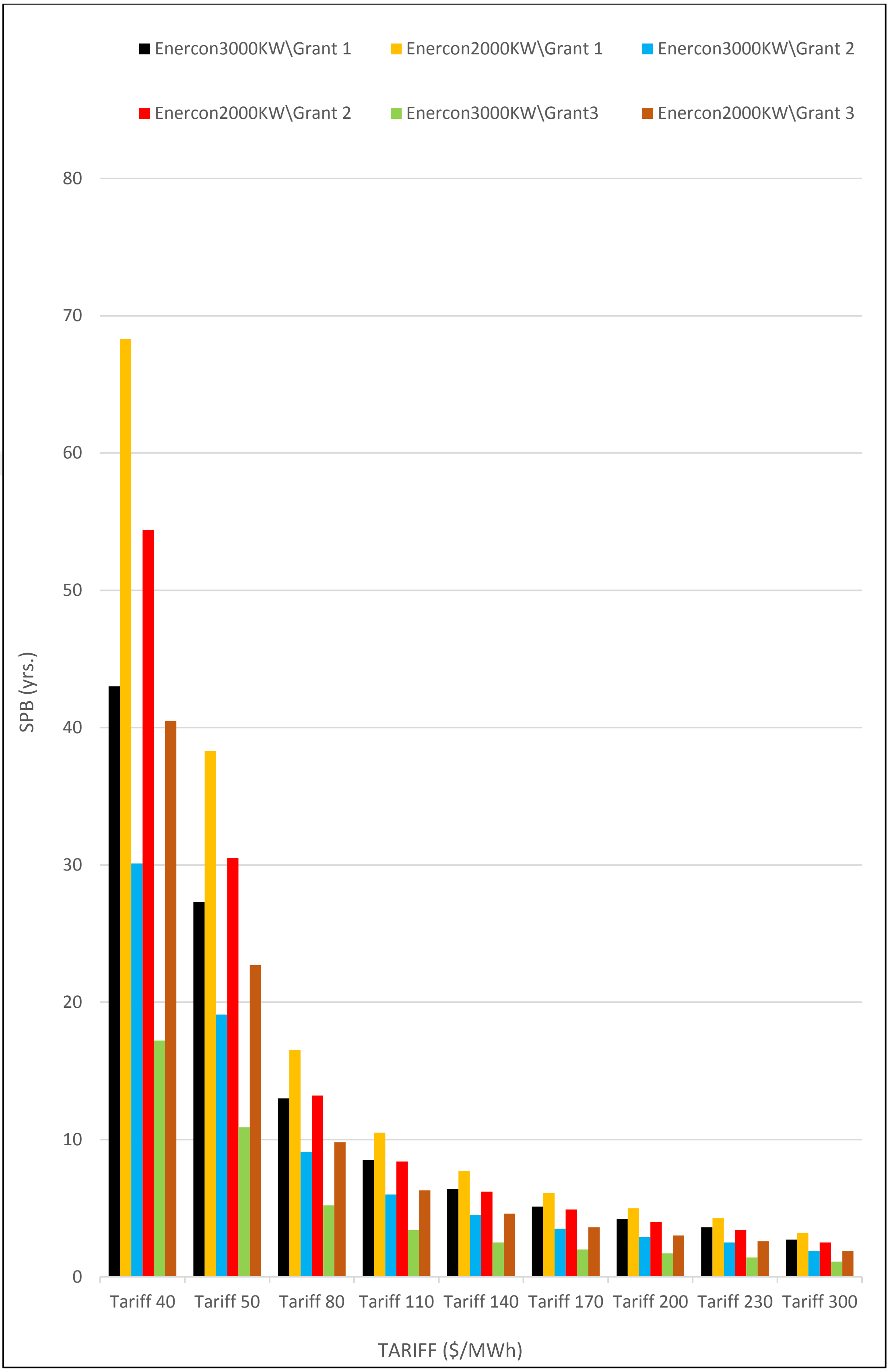

Figure 4.11: Simple Payback Period with tariffs with the effect on all grants for all Enercon (3000, 2000) kW projects at the Al-Amarah site\GHG income ($0/tCO$_2$)

4.5.2 Evaluation of Projects by Calculating Net Present Value (NPV) Versus Tariffs by the Effect of The Grants

Table 4.6 illustrates the calculations for NPV versus Tariffs showing effects the grants for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Amarah site, where we note the gradual rise of the NPV value with an increased tariff, as shown in Figure 4.12 and Fig. 4.13.

Table 4.6: NPV versus Tariffs showing the effects on grants for the 75MW wind project at the Al-Amarah site

Tariff ($/MWh)	NPV ($)					
	Wind project Enercon- 3000 KW/25 unit turbine			Wind project Enercon- 2000 KW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	-91,899,418	–60,331,385	–28,763,352	-148,137,256	–116,569,223	–85,001,190
50	-79,108,043	–47,540,010	–15,971,977	-131,987,724	–100,419,691	–68,851,658
80	-40,733,919	–9,165,886	22,402,147	-83,539,126	–51,971,093	–20,403,060
110	–2,359,795	29,208,238	60,776,271	-35,090,528	–3,522,495	28,045,538
140	36,014,330	67,582,363	99,150,396	13,358,070	44,926,103	76,494,136
170	74,388,454	105,956,487	137,524,520	61,806,668	93,374,701	124,942,734
200	112,762,578	144,330,611	175,898,644	110,255,266	141,823,299	173,391,332
230	151,136,702	182,704,735	214,272,768	158,703,864	190,271,897	221,839,930
300	240,676,325	272,244,358	303,812,391	271,750,593	303,318,626	334,886,659

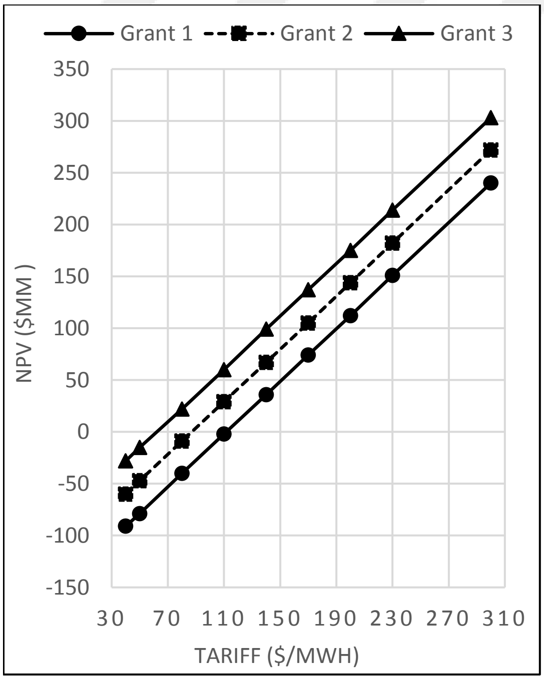

Figure 4.12: NPV versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Amarah site\GHG income ($0/tCO₂)

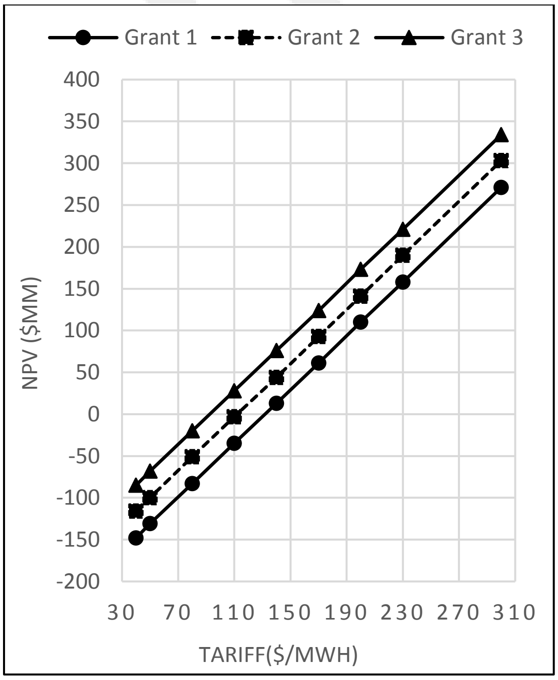

Figure 4.13: NPV versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Amarah site\GHG income ($0/$tCO_2$)

4.5.3 Evaluation of projects by calculating Annual Life Cycle Savings (ALCS) Versus Tariffs by the Effect of The Grants

Table 4.7 illustrates the calculations of ALCS versus Tariffs showing effects the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Amarah site, where we note the gradual rise of the ALCS value with increased tariffs, as shown in Figure 4.14 and Fig. 4.15.

Table 4.7: ALCS versus Tariffs showing the effects on grants for the 75MW wind project at Al-Amarah site

Tariff ($/MWh)	ALCS ($/year)					
	Wind project Enercon- 3000 KW/25 unit turbine			Wind project Enercon- 2000 KW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	-10,124,382	–6,646,592	–3,168,803	-16,319,996	–12,842,207	–9,364,417
50	–8,715,181	–5,237,391	–1,759,602	-14,540,833	–11,063,044	–7,585,254
80	–4,487,577	–1,009,788	2,468,001	–9,203,344	–5,725,555	–2,247,766
110	–259,974	3,217,815	6,695,605	–3,865,856	–388,066	3,089,723
140	3,967,629	7,445,419	10,923,208	1,471,633	4,949,422	8,427,212
170	8,195,233	11,673,022	15,150,811	6,809,121	10,286,911	13,764,700
200	12,422,836	15,900,625	19,378,415	12,146,610	15,624,399	19,102,189
230	16,650,439	20,128,228	23,606,018	17,484,099	20,961,888	24,439,677
300	26,514,847	29,992,636	33,470,425	29,938,239	33,416,028	36,893,818

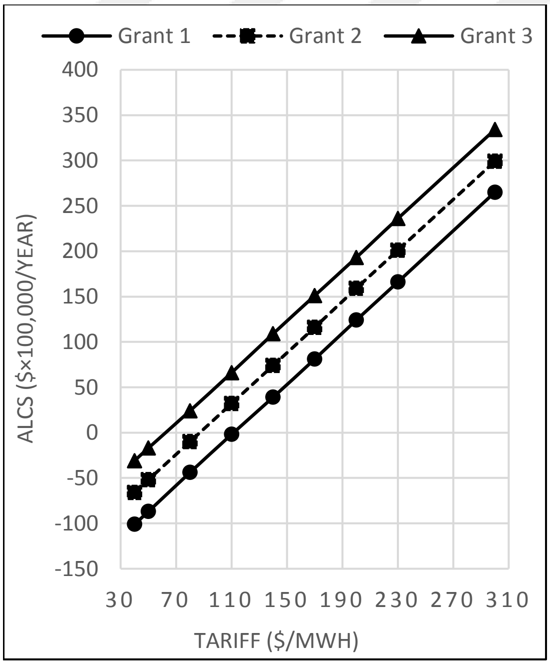

Figure 4.14: ALCS versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Amarah site\GHG income ($0/tCO$_2$)

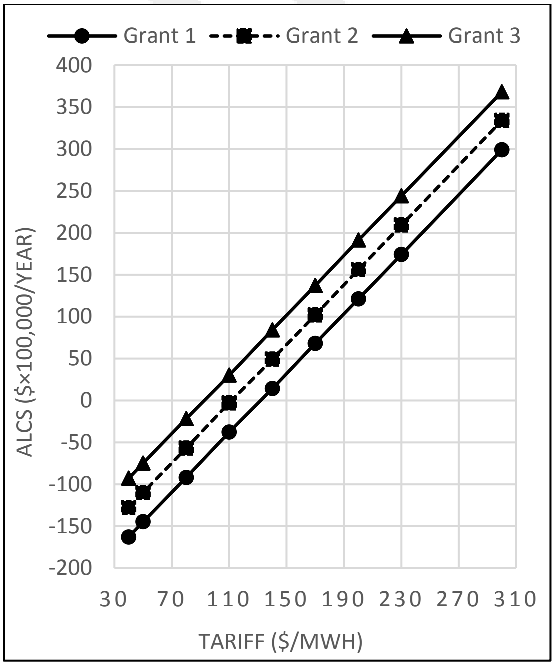

Figure 4.15: ALCS versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Amarah site\GHG income ($0/tCO$_2$)

4.6 Mandali Site (Financial / Grant)

4.6.1 Evaluation of Projects by Calculating a Simple Payback Period (SPB) Versus Tariffs with Effects on Grants

Table 4.8 illustrates the calculations of the SPB versus Tariffs showing the effects on the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Mandali site, where we note a drop in SPB with an increased tariff, as shown in Figure 4.16 and Fig. 4.17.

Table 4.8: SPB versus Tariffs showing the effects on grants for the 75MW wind project at the Mandali site

Tariff ($/MWh)	SPB(years)					
	Wind project Enercon-3000 kW/25 unit			Wind project Enercon-2000 kW/38 unit		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	61.8	43.3	24.7	107.6	85.8	63.9
50	36	25.2	14	51.5	41	30.6
80	16	11.2	6.4	20.1	16	11.9
110	10.3	7.2	4.1	12.5	9.9	7.4
140	7.6	5.3	3	9	7.2	5.4
170	6	4.2	2.4	7.1	5.7	4.2
200	4.9	3.5	2	5.8	4.7	3.5
230	4.2	3	1.7	5	3.9	2.9
300	3.1	2.2	1.3	3.7	2.9	2.2

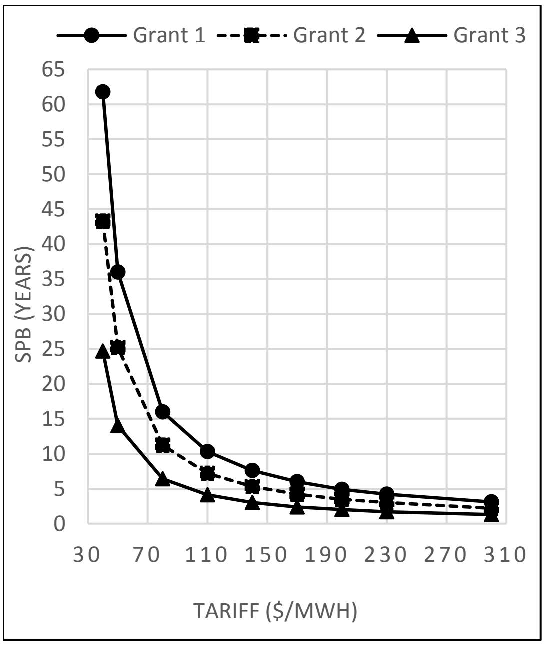

Figure 4.16: SPB versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Mandali site\GHG income ($0/tCO$_2$)

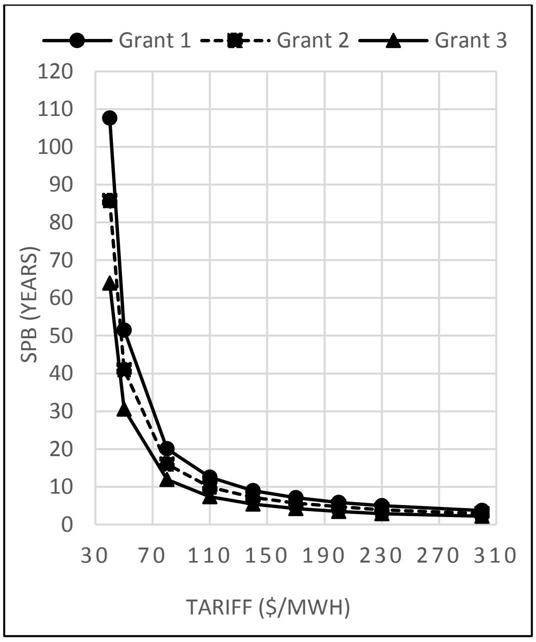

Figure 4.17: SPB versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Mandali site\GHG income ($0/tCO$_2$)

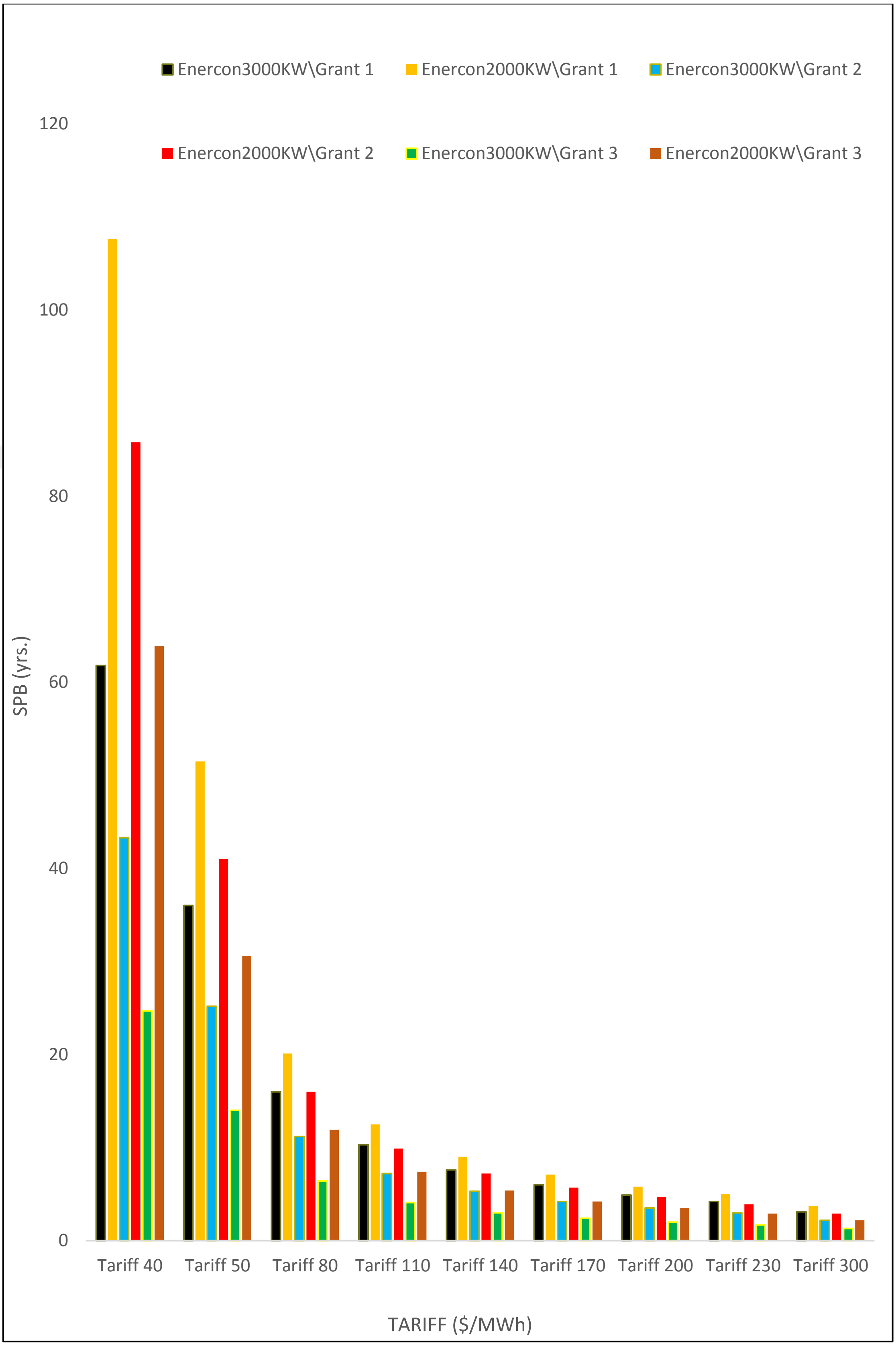

Figure 4.18: Simple Payback Period with tariffs with the effect on all grants for all Enercon (3000, 2000) kW projects at the Mandali site\GHG income ($0/tCO$_2$)

4.6.2 Evaluation of Projects by Calculating Net Present Value (NPV) Versus Tariffs Showing the Effects on Grants

Table 4.9 illustrates the calculations of NPV versus Tariffs showing the effects on the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Mandali site, where we note a gradual rise of the NPV value with an increased tariff, as shown in Figure 4.19 and Fig. 4.20.

Table 4.9: NPV versus Tariffs showing the effects on grants for the 75MW wind project at the Mandali site

Tariff ($/MWh)	NPV ($)					
	Wind project Enercon- 3000 KW/25 unit turbine			Wind project Enercon- 2000 KW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	–98,683,325	–67,115,292	–35,547,259	-155,668,800	–124,100,767	–92,532,734
50	–87,587,927	–56,019,894	–24,451,861	-141,402,154	–109,834,121	–78,266,088
80	–54,301,734	–22,733,701	8,834,332	–98,602,214	–67,034,181	–35,466,148
110	–21,015,540	10,552,493	42,120,526	–55,802,274	–24,234,241	7,333,792
140	12,270,654	43,838,687	75,406,720	–13,002,334	18,565,699	50,133,732
170	45,556,847	77,124,880	108,692,913	29,797,606	61,365,639	92,933,672
200	78,843,041	110,411,074	141,979,107	72,597,546	104,165,579	135,733,612
230	112,129,235	143,697,268	175,265,301	115,397,486	146,965,519	178,533,552
300	189,797,020	221,365,053	252,933,086	215,264,012	246,832,045	278,400,078

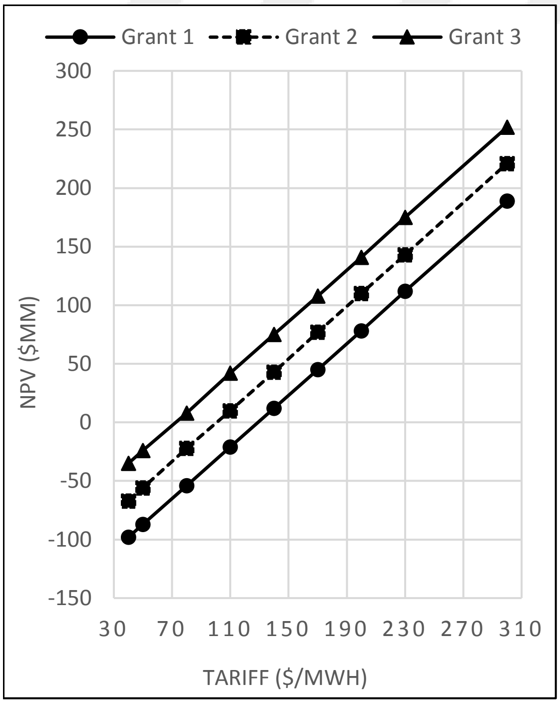

Figure 4.19: NPV versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Mandali site\GHG income ($0/tCO$_2$)

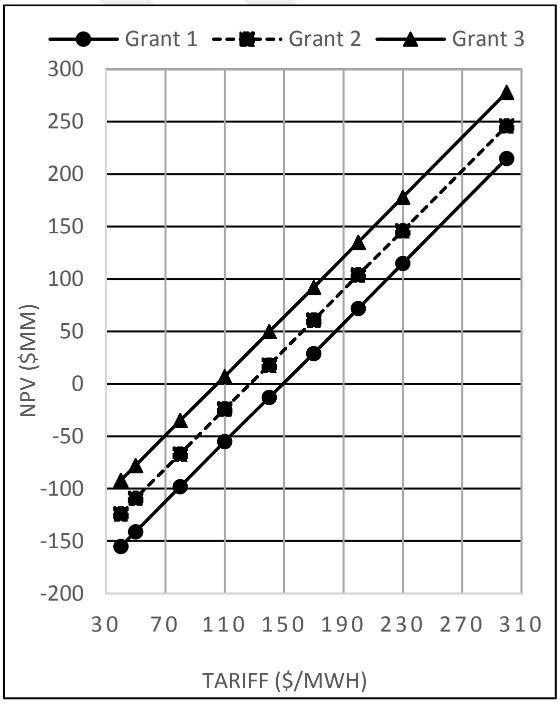

Figure 4.20: NPV versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Mandali site\GHG income ($0/tCO$_2$)

4.6.3 Evaluation of Projects by Calculating Annual Life Cycle Savings (ALCS) Versus Tariffs Showing the Effects on Grants

Table 4.10 illustrates the calculations of ALCS versus Tariff with the effects on grants for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Mandali site, where we note a gradual rise of the ALCS value with an increased tariff, as shown in Figure 4.21 and Fig. 4.22.

Table 4.10: ALCS versus Tariffs showing the effect of grants on the 75MW wind project at the Mandali site

Tariff ($/MWh)	ALCS ($/year)					
	Wind project Enercon- 3000 KW/25 unit turbine			Wind project Enercon- 2000 KW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	–10,871,752	–7,393,962	–3,916,173	–17,149,732	–13,671,942	–10,194,153
50	–9,649,393	–6,171,604	–2,693,814	–15,578,003	–12,100,213	–8,622,424
80	–5,982,317	–2,504,528	973,261	–10,862,816	–7,385,026	–3,907,237
110	–2,315,242	1,162,548	4,640,337	–6,147,629	–2,669,840	807,950
140	1,351,834	4,829,624	8,307,413	–1,432,442	2,045,347	5,523,137
170	5,018,910	8,496,699	11,974,489	3,282,745	6,760,534	10,238,323
200	8,685,986	12,163,775	15,641,565	7,997,932	11,475,721	14,953,510
230	12,353,062	15,830,851	19,308,640	12,713,119	16,190,908	19,668,697
300	20,909,572	24,387,361	27,865,150	23,715,221	27,193,011	30,670,800

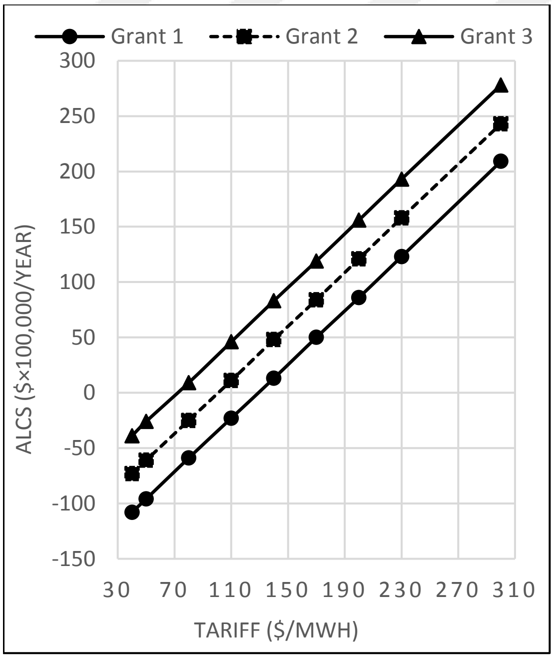

Figure 4.21: ALCS versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Mandali site\GHG income ($0/tCO$_2$)

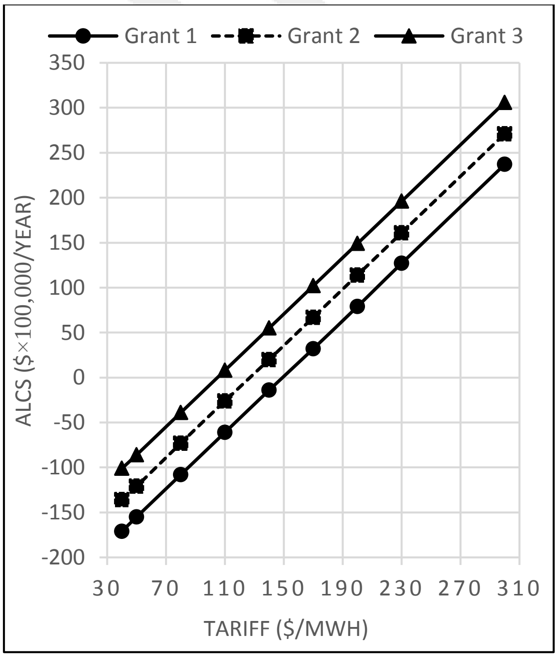

Figure 4.22: ALCS versus Tariffs showing the effects on grants for the 75MW wind project with the Enerc on-E82-E2-2000 kW turbine at the Mandali site\GHG income ($0/tCO$_2$)

4.7 Samarra Site (Financial / Grant)

4.7.1 Evaluation of Projects by Calculating a Simple Payback Period (SPB) Versus Tariffs with Effects on Grants

Table 4.11 illustrates the calculations of the SPB versus Tariffs showing the effects on the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Samarra site, where we note a drop in SPB with an increased tariff, as shown in Figure 4.23 and Fig. 4.24.

Table 4.11: SPB versus Tariffs showing the effects on grants for the 75MW wind project / Samarra site

Tariff ($/MWh)	SPB (years)					
	Wind project Enercon-3000 kW/25 unit			Wind project Enercon-2000 kW/38 unit		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	97.8	68.5	39.1	213.8	170.3	126.8
50	49.1	34.4	19.7	73.3	58.4	43.5
80	19.7	13.8	7.9	24.7	19.6	14.6
110	12.3	8.6	4.9	14.8	11.8	8.8
140	9	6.3	3.6	10.6	8.4	6.3
170	7	4.9	2.8	8.2	6.6	4.9
200	5.8	4.1	2.3	6.7	5.4	4
230	4.9	3.5	2	5.7	4.5	3.4
300	3.7	2.6	1.5	4.2	3.3	2.5

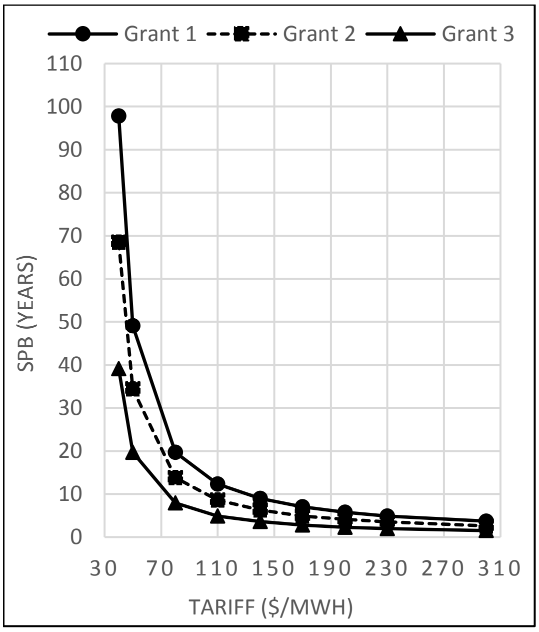

Figure 4.23: SPB versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Samarra site\GHG income ($0/tCO$_2$)

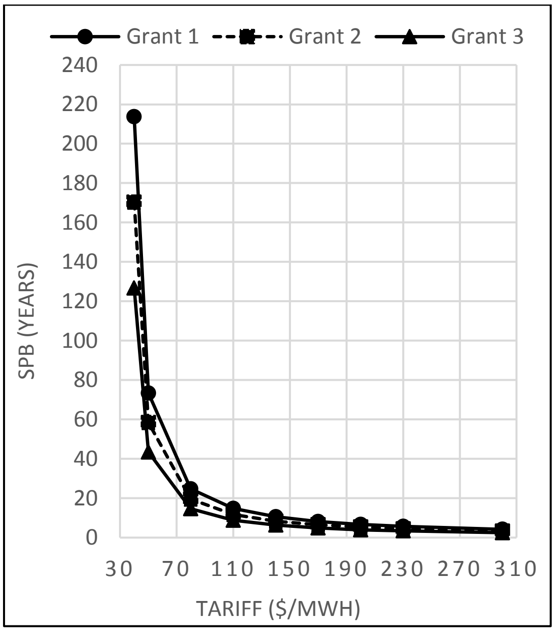

Figure 4.24: SPB versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Samarra site\GHG income ($0/tCO$_2$)

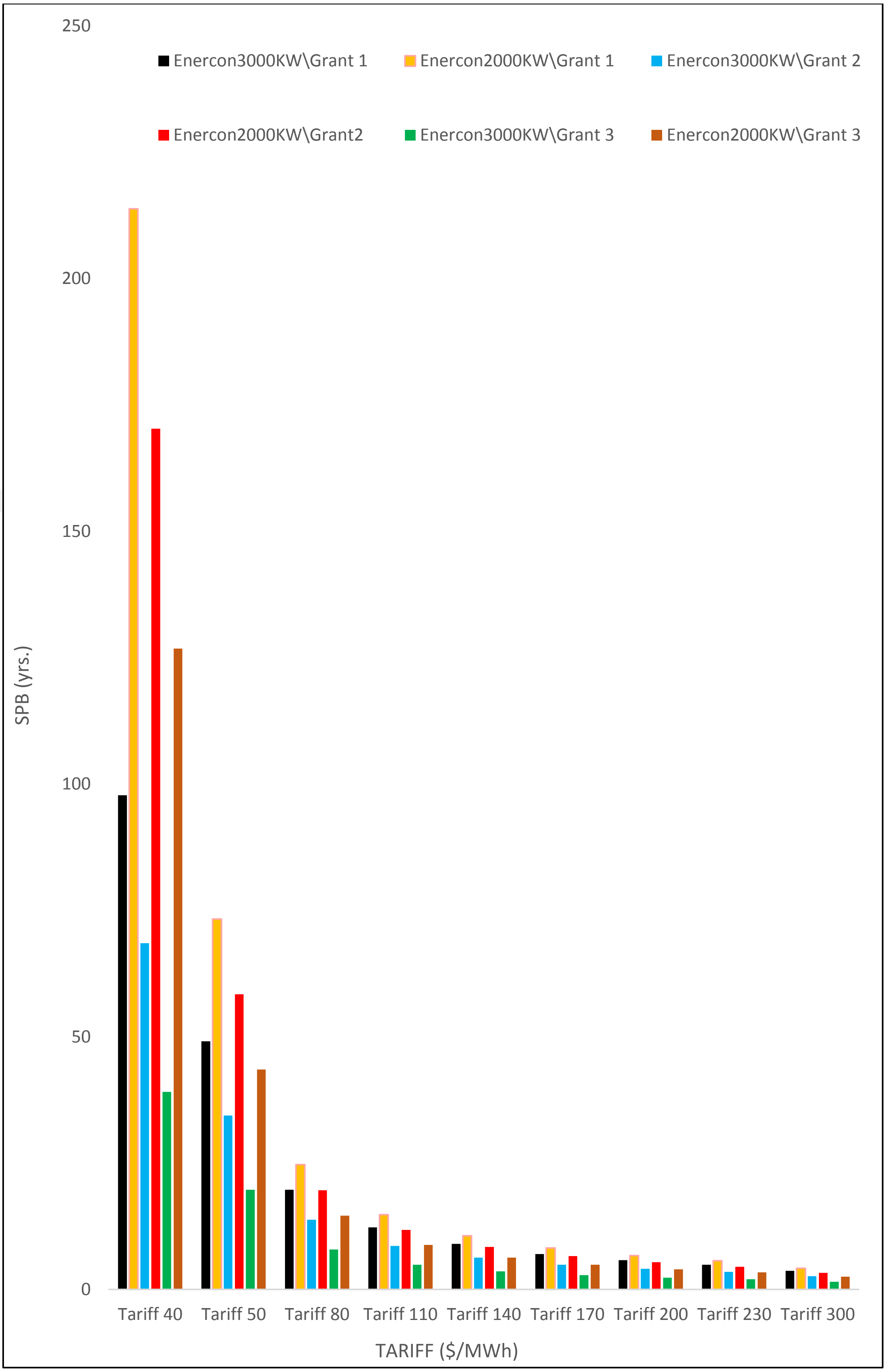

Figure 4.25: Simple Payback Period with tariffs with the effect on all grants for all Enercon (3000, 2000) kW projects at the Samarra site\GHG income (\$0/tCO$_2$)

4.7.2 Evaluation of Projects by Calculating Net Present Value (NPV) Versus Tariffs Showing the Effects on Grants

Table 4.12 illustrates the calculations of NPV versus Tariffs showing the effects on the grants to the projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Samarra site, where we note a gradual rise of the NPV value with an increased tariff, as shown in Figure 4.26 and Fig. 4.27.

Table 4.12: NPV versus Tariffs showing the effects on grants for the 75MW wind project at the Samarra site

Tariff ($/MWh)	NPV ($)					
	Wind project Enercon- 3000 KW/25 unit turbine			Wind project Enercon- 2000 KW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	-104,369,832	-72,801,799	-41,233,766	-162,167,563	-130,599,530	-99,031,497
50	-94,696,061	-63,128,028	-31,559,995	-149,525,607	-117,957,574	-86,389,541
80	-65,674,747	-34,106,714	-2,538,681	-111,599,739	-80,031,706	-48,463,673
110	-36,653,433	-5,085,400	26,482,633	-73,673,871	-42,105,838	-10,537,805
140	-7,632,120	23,935,913	55,503,946	-35,748,003	-4,179,970	27,388,063
170	21,389,194	52,957,227	84,525,260	2,177,866	33,745,899	65,313,932
200	50,410,508	81,978,541	113,546,574	40,103,734	71,671,767	103,239,800
230	79,431,821	110,999,854	142,567,887	78,029,602	109,597,635	141,165,668
300	147,148,220	178,716,253	210,284,286	166,523,264	198,091,327	229,659,360

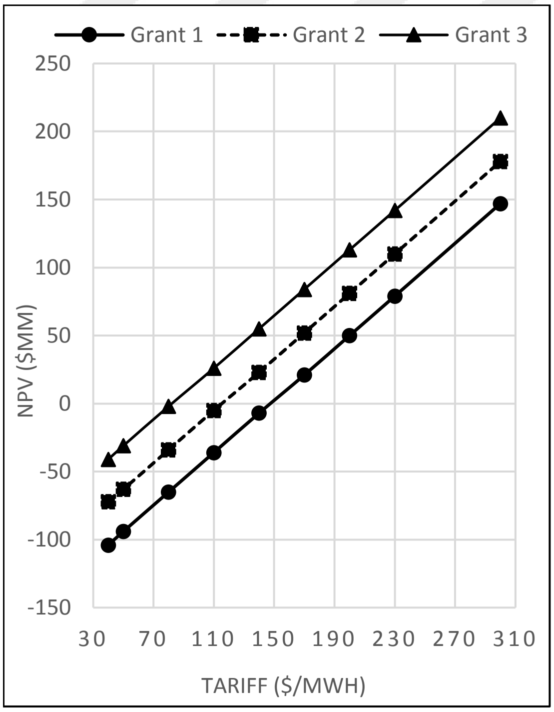

Figure 4.26: NPV versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Samarra site\GHG income ($0/tCO$_2$)

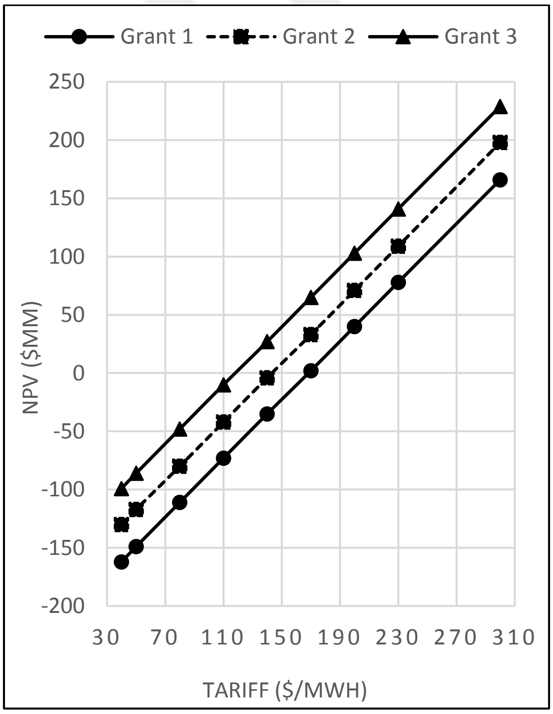

Figure 4.27: NPV versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Samarra site\GHG income ($0/tCO$_2$)

4.7.3 Evaluation of Projects by Calculating Annual Life Cycle Savings (ALCS) Versus Tariffs Showing the Effects on Grants

Table 4.13 illustrates the calculations of ALCS versus Tariffs with the effects on grants for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Samarra site, where we note a gradual rise of the ALCS value with an increased tariff, as shown in Figure 4.28 and Fig. 4.29.

Table 4.13: ALCS versus Tariffs showing the effect of grants on the 75MW wind project at the Samarra site

Tariff ($/MWh)	ALCS ($/year)					
	Wind project Enercon- 3000 KW/25 unit turbine			Wind project Enercon- 2000 KW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
40	-11,498,223	-8,020,434	-4,542,644	-17,865,688	-14,387,898	-10,910,109
50	-10,432,482	-6,954,693	-3,476,904	-16,472,948	-12,995,159	-9,517,369
80	-7,235,260	-3,757,471	-279,682	-12,294,728	-8,816,939	-5,339,149
110	-4,038,038	-560,249	2,917,541	-8,116,508	-4,638,719	-1,160,930
140	-840,816	2,636,973	6,114,763	-3,938,289	-460,499	3,017,290
170	2,356,406	5,834,196	9,311,985	239,931	3,717,721	7,195,510
200	5,553,628	9,031,418	12,509,207	4,418,151	7,895,940	11,373,730
230	8,750,851	12,228,640	15,706,429	8,596,371	12,074,160	15,551,949
300	16,211,036	19,688,825	23,166,614	18,345,550	21,823,340	25,301,129

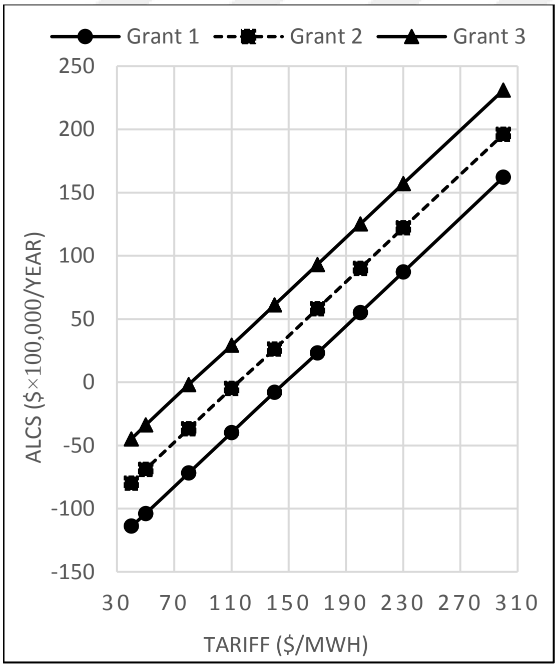

Figure 4.28: ALCS versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Samarra site\GHG income ($0/tCO$_2$)

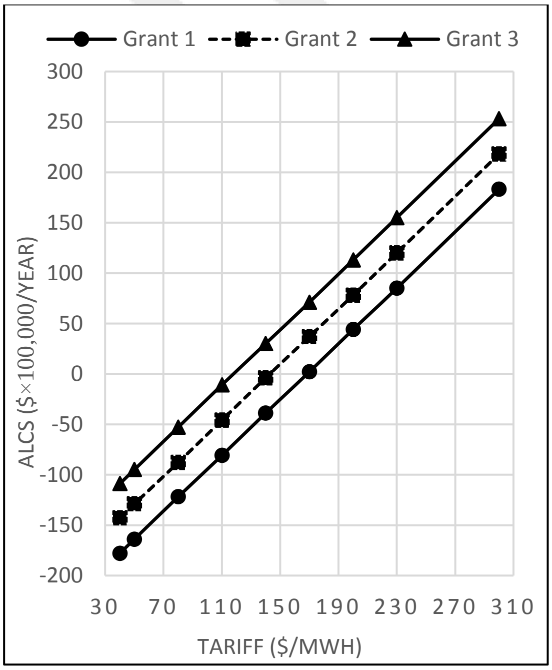

Figure 4.29: ALCS versus Tariffs showing the effects on grants for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Samarra site\GHG income ($0/tCO$_2$)

4.8 Situation 2: Evaluation of Projects by Calculating (SPB, NPV, ALCS) Versus Tariffs with Effects on GHG Reduction Income for All Sites\ Grant 1

GHG reduction income: The model calculates the annual GHG reduction income which represents the income generated by the sale or exchange of the GHG reductions. It is calculated from the annual net GHG reduction and the GHG reduction credit rate. The annual value of GHG reduction income is escalated at the GHG reduction credit escalation rate [48].

Considering the effects of GHG will change the results obtained in the previous section. Two different GHG reduction incomes will be presented; 8$/tCO2 and 25$/tCO2. The reason for choosing those two-reduction income is that, according to P. Luckow et al [52], the mid case CO2 forecast show that the price of CO2 will start at $20 per ton in 2020 and will increase to $26 per ton in 2030. We will calculate SPB, NPV and ALCS versus Tariff under the effect of greenhouse gases reduction income ($/tCO2) for the projects under () at each site.

4.9 Al-Nasiriyah Site (Financial / GHG Income)

4.9.1 Evaluation of Projects by Calculating a Simple Payback Period (SPB) Versus Tariffs with Effects on GHG Reduction Income

Table 4.14 illustrates calculations of SPB versus Tariffs with effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Nasiriyah site.

a- For the 75MW wind project with the Enercon-E82-E3-3000 kW/25 unit:

- At a tariff of $40/MWh, the simple payback becomes 24.3 years with a GHG reduction income of $8/t$CO_2$ and decreases to 15 years with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $80/MWh, the simple payback becomes 9.9 years with a GHG reduction income of $8/t$CO_2$ and decreases to 7.9 years with a GHG reduction income of $25/t$CO_2$.

- At a tariff of \$140/MWh, the simple payback becomes 5.3 years with a GHG reduction income of \$8/tCO_2 and decreases to 4.6 years with a GHG reduction income of \$25/tCO_2.
- At a tariff of \$300/MWh, the simple payback becomes 2.3 years with a GHG reduction income of \$8/tCO_2 and decreases to 2.2 years with a GHG reduction income of \$25/tCO_2, as shown in Figure 4.30.

b- For the 75MW wind project with the Enercon-E82-E2-2000 kW/38 unit:

- At a tariff of \$40/MWh, the simple payback becomes 34.4 years with a GHG reduction income of \$8/tCO_2 and decreases to 19.8 years with a GHG reduction income of \$25/tCO_2.
- At a tariff of \$80 MWh, the simple payback becomes 12.6 years with a GHG reduction income of \$8/tCO_2 and decreases to 9.9 years with a GHG reduction income of \$25/tCO_2.
- At a tariff of \$140/MWh, the simple payback becomes 6.5 years with a GHG reduction income of \$8/tCO_2 and decreases to 5.7 years with a GHG reduction income of \$25/tCO_2.
- At a tariff of \$300/MWh, the simple payback becomes 2.8 years with a GHG reduction income of \$8/tCO_2 and decreases to 2.7 years with a GHG reduction income of \$25/tCO_2, as shown in Figure 4.31.

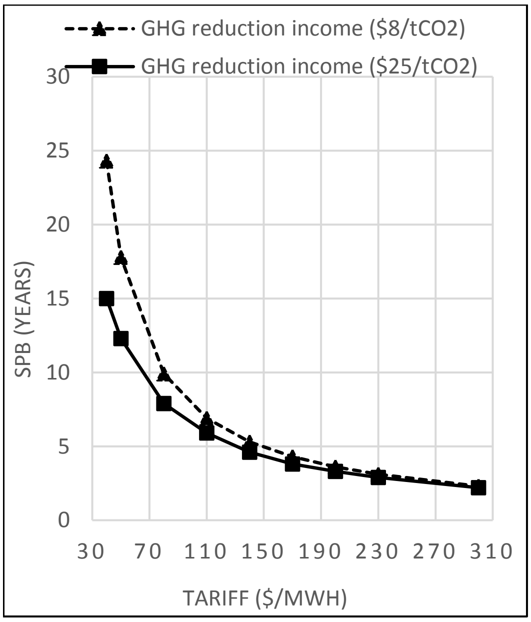

Figure 4.30: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Nasiriyah site/ grant 1

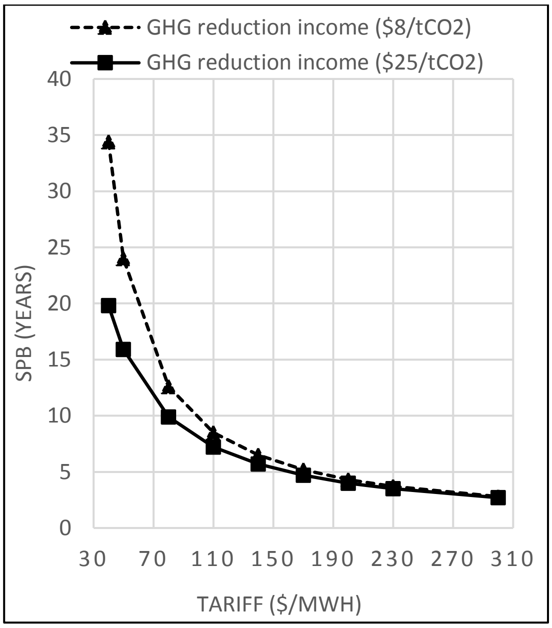

Figure 4.31: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Nasiriyah site/ grant 1

Table 4.14: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project at the Al-Nasiriyah site

Tariff ($/MWh)	SPB (years)			
	Wind project Enercon-3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$
40	24.3	15	34.4	19.8
50	17.8	12.3	24	15.9
80	9.9	7.9	12.6	9.9
110	6.9	5.9	8.5	7.2
140	5.3	4.6	6.5	5.7
170	4.3	3.8	5.2	4.7
200	3.6	3.3	4.3	4
230	3.1	2.9	3.7	3.5
300	2.3	2.2	2.8	2.7

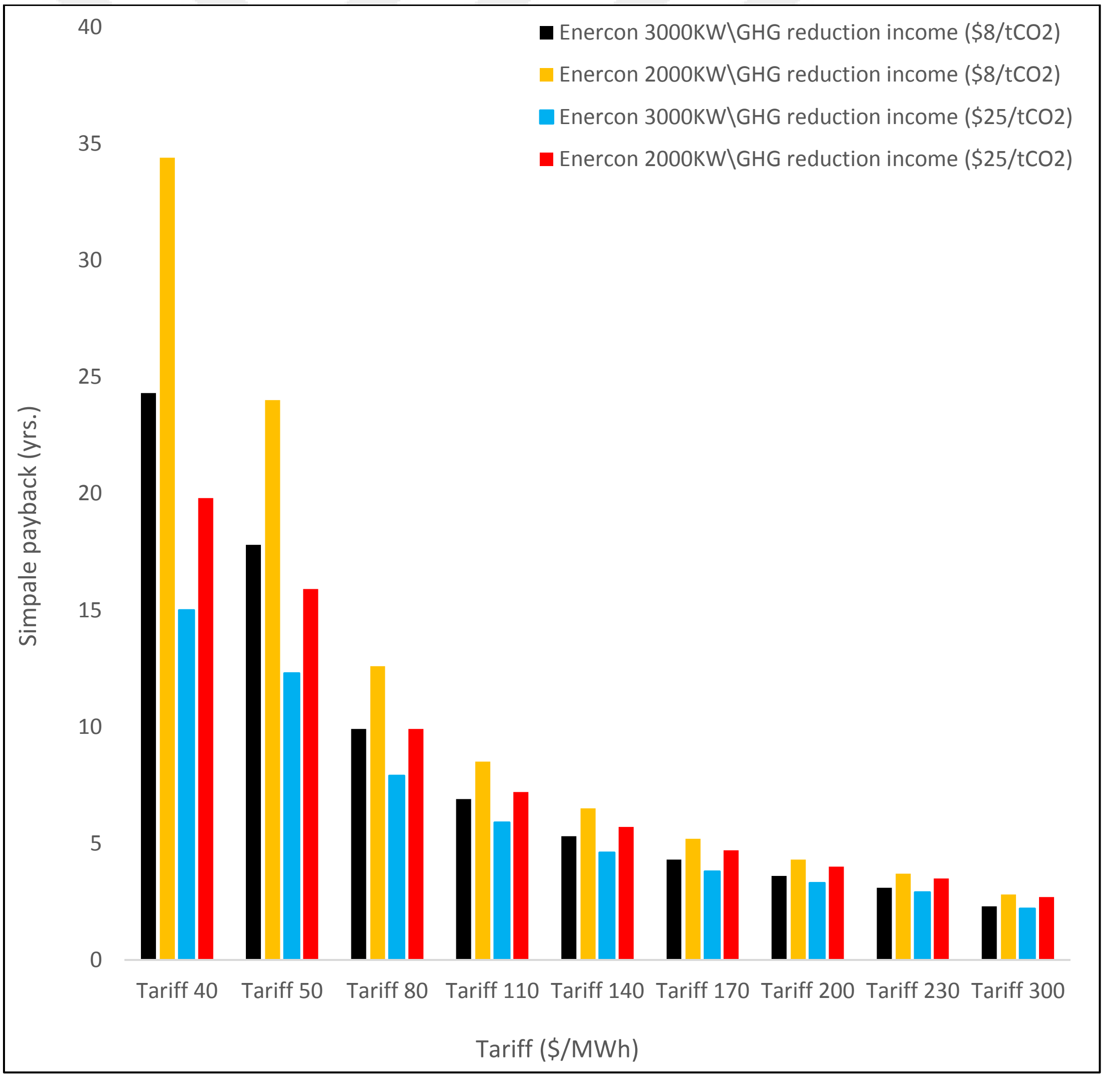

Figure 4.32: SPB with tariffs showing the effects on all GHG reduction incomes for all Enercon (3000, 2000) kW projects at the Al-Nasiriyah site/ grant 1

4.9.2 Evaluation of Projects by Calculating Net Present Value (NPV) Versus Tariffs with The Effect on GHG Reduction Income

Table 4.15 illustrates the calculations of NPV versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Nasiriyah site.

a- For the 75MW wind project with the Enercon-E82-E3-3000 kW/25 unit:

- At a tariff of $40/MWh, the Net Present Value becomes -$74,435,841 with a GHG reduction income of $8/t$CO_2$ and reaching to -$49,457,681 with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $80/MWh, the Net Present Value becomes -$17,561,195 with a GHG reduction income of $8/t$CO_2$ and increases to $7,416,966 with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $140/MWh, the Net Present Value becomes $67,750,775 with a GHG reduction income of $8/t$CO_2$ and increases to $92,728,936 with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $300/MWh, the Net Present Value becomes $295,249,362 with a GHG reduction income of $8/t$CO_2$ and increases to $320,227,523 with a GHG reduction income of $25/t$CO_2$, as shown in Figure 4.33.

b- For the 75-MW wind project with the Enercon-E82-E2-2000 kW/38 unit:

- At a tariff of $40/MWh, the Net Present Value becomes -$127,341,545 with a GHG reduction income of $8/t$CO_2$ and reaching to -$96,261,699 with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $80/MWh, the Net Present Value becomes -$56,573,513 with a GHG reduction income of $8/t$CO_2$ and reaching to -$25,493,667 with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $140 MWh, the Net Present Value becomes $49,578,535 with a GHG reduction income of $8/t$CO_2$ and increases to $80,658,382 with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $300/MWh, the Net Present Value becomes $332,650,664 with a GHG reduction income of $8/t$CO_2$ and increases to $363,730,510 with a GHG reduction income of $25/t$CO_2$, as shown in Figure 4.34.

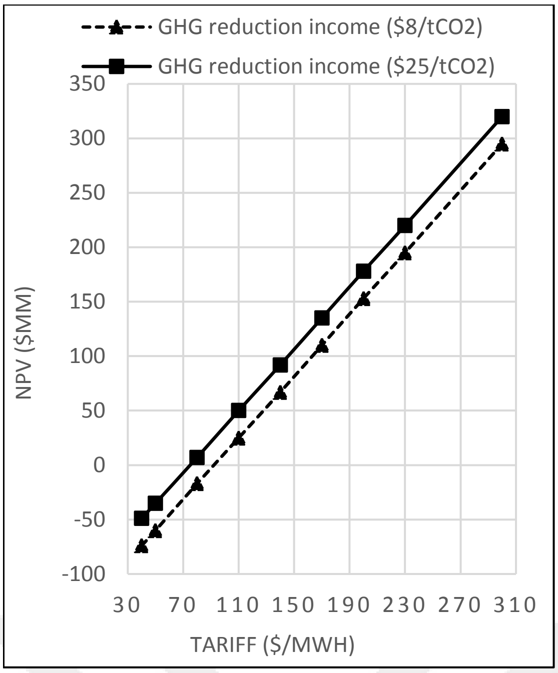

Figure 4.33: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Nasiriyah site/ grant 1

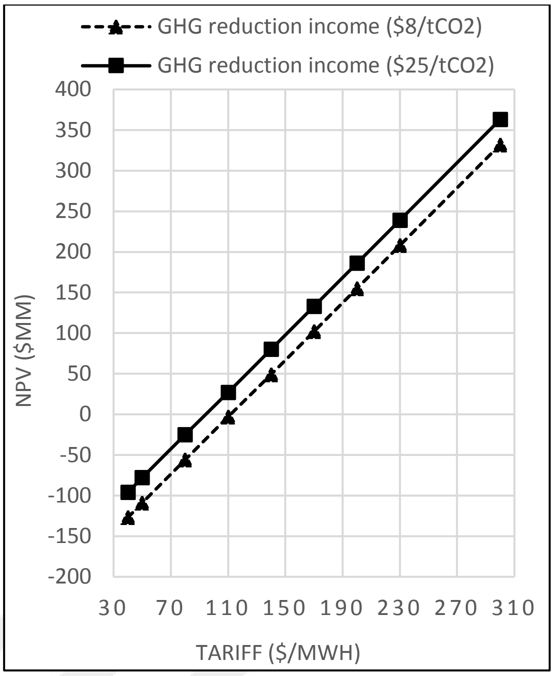

Figure 4.34: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Nasiriyah site/ grant 1

Table 4.15: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project at the Al-Nasiriyah site

Tariff ($/MWh)	NPV ($)			
	Wind project Enercon-3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$
40	–74,435,841	–49,457,681	–127,341,545	–96,261,699
50	–60,217,180	–35,239,019	–109,649,537	–78,569,691
80	–17,561,195	7,416,966	–56,573,513	–25,493,667
110	25,094,790	50,072,951	–3,497,489	27,582,358
140	67,750,775	92,728,936	49,578,535	80,658,382
170	110,406,761	135,384,921	102,654,560	133,734,406
200	153,062,746	178,040,906	155,730,584	186,810,430
230	195,718,731	220,696,891	208,806,608	239,886,454
300	295,249,362	320,227,523	332,650,664	363,730,510

4.9.3 Evaluation of Projects by Calculating Annual Life Cycle Saving (ALCS) Versus Tariffs with Effects on GHG Reduction Income

Table 4.16 illustrates the calculations of ALCS versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Nasiriyah site.

a- For the 75MW wind project with the Enercon-E82-E3-3000 kW/25 unit:

- At a tariff of $40/MWh, the Annual Life Cycle Savings becomes -$8,200,453/year with a GHG reduction income of $8/t$CO_2$ and reaching to -$5,448,657/year with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $80/MWh, the Annual Life Cycle Savings becomes -$1,934,683/year with a GHG reduction income of $8/t$CO_2$ and increases to $817,113/year with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $140/MWh, the Annual Life Cycle Savings becomes $7,463,972/year with a GHG reduction income of $8/t$CO_2$ and increases to $10,215,768/year with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $300/MWh, the Annual Life Cycle Savings becomes $32,527,053/year with a GHG reduction income of $8/t$CO_2$ and increases to $35,278,849/year with a GHG reduction income of $25/t$CO_2$, as shown in Figure 4.35.

b- For the 75MW wind project with the Enercon-E82-E2-2000 kW/38 unit:

- At a tariff of $40/MWh, the Annual Life Cycle Savings becomes -$14,028,973/year with a GHG reduction income of $8/t$CO_2$ and reaching to -$10,604,966/year with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $80/MWh, the Annual Life Cycle Savings becomes -$6,232,595/year with a GHG reduction income of $8/t$CO_2$ and reaching to -$2,808,588/year with a GHG reduction income of $25/t$CO_2$.
- At a tariff of $140/MWh, the Annual Life Cycle Savings becomes $5,461,972/year with a GHG reduction income of $8/t$CO_2$ and increases to $8,885,978/year with a GHG reduction income of $25/t$CO_2$.
- a tariff of $300/MWh, the Annual Life Cycle Savings becomes $36,647,482/year with a GHG reduction income of $8/tCO2 and increases

to \$40,071,489/year with a GHG reduction income of \$25/tCO2, as shown in Figure 4.36.

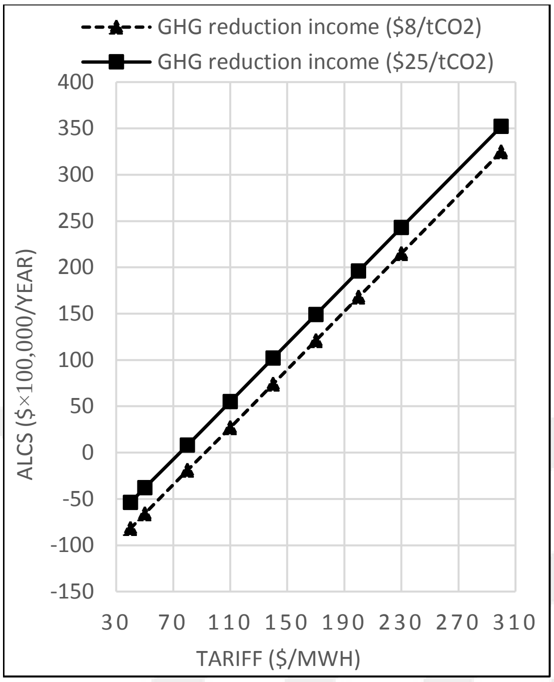

Figure 4.35: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Nasiriyah site/ grant 1

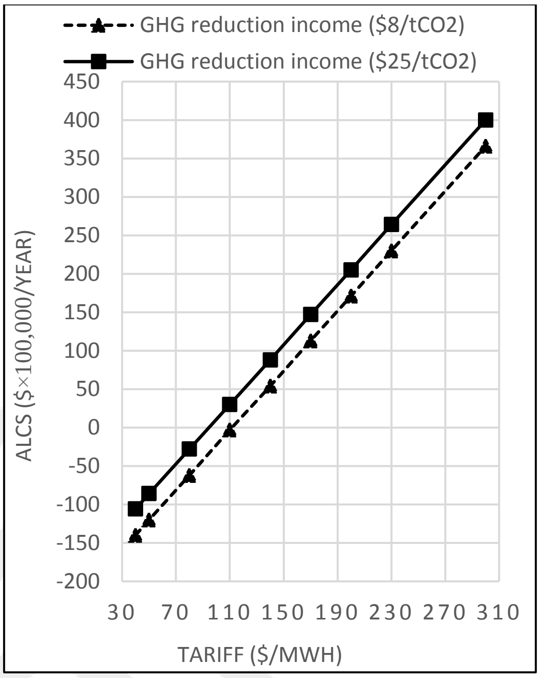

Figure 4.36: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Nasiriyah site/ grant 1

Table 4.16: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project at the Al-Nasiriyah site

Tariff (\$/MWh)	ALCS (\$/year)			
	Wind project Enercon-3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income \$8/tCO_2	GHG reduction income \$25/tCO_2	GHG reduction income \$8/tCO_2	GHG reduction income \$25/tCO_2
40	–8,200,453	–5,448,657	–14,028,973	–10,604,966
50	–6,634,011	–3,882,215	–12,079,878	–8,655,871
80	–1,934,683	817,113	–6,232,595	–2,808,588
110	2,764,645	5,516,440	–385,312	3,038,695
140	7,463,972	10,215,768	5,461,972	8,885,978
170	12,163,300	14,915,096	11,309,255	14,733,262
200	16,862,628	19,614,423	17,156,538	20,580,545
230	21,561,955	24,313,751	23,003,821	26,427,828
300	32,527,053	35,278,849	36,647,482	40,071,489

4.10 Al-Amarah Site (Financial / GHG Income)

4.10.1 Evaluation of Projects by Calculating Simple Payback Period (SPB) Versus Tariffs with Effects on GHG Reduction Income

Table 4.17 illustrates the calculations of SPB versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Amarah site, where we note a drop in SPB with increased tariffs, as shown in Figure 4.37 and Fig. 4.38.

Table 4.17: SPB versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Al-Amarah site

Tariff ($/MWh)	SPB (years)			
	Wind project Enercon- 3000 kW/25 unit		Wind project Enercon- 2000 kW/38 unit	
	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$
40	29.4	17.6	42	23.1
50	21.1	14.2	28.3	18.2
80	11.4	9.1	14.4	11.2
110	7.8	6.6	9.6	8.1
140	6	5.2	7.2	6.3
170	4.8	4.3	5.8	5.2
200	4	3.7	4.8	4.4
230	3.5	3.2	4.1	3.8
300	2.6	2.5	3.1	2.9

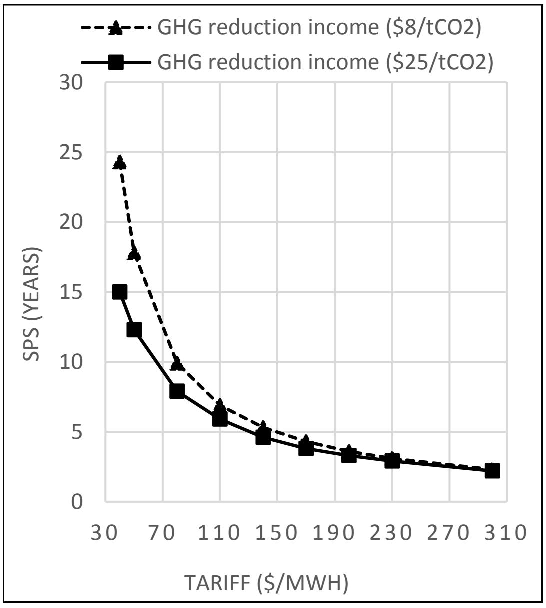

Figure 4.37: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Amarah site/ grant 1

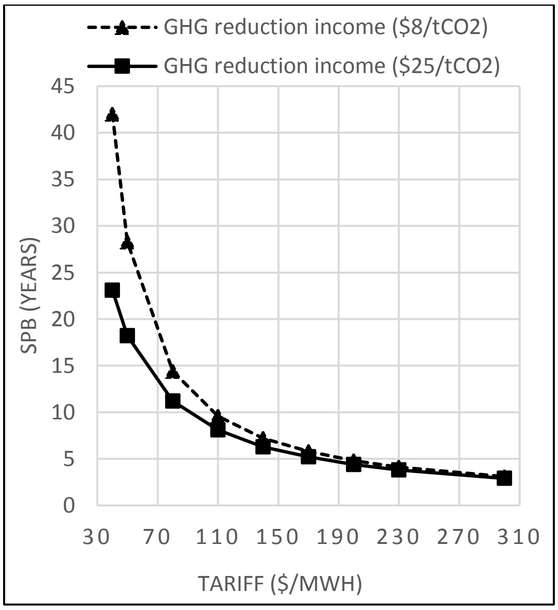

Figure 4.38: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Amarah site/ grant 1

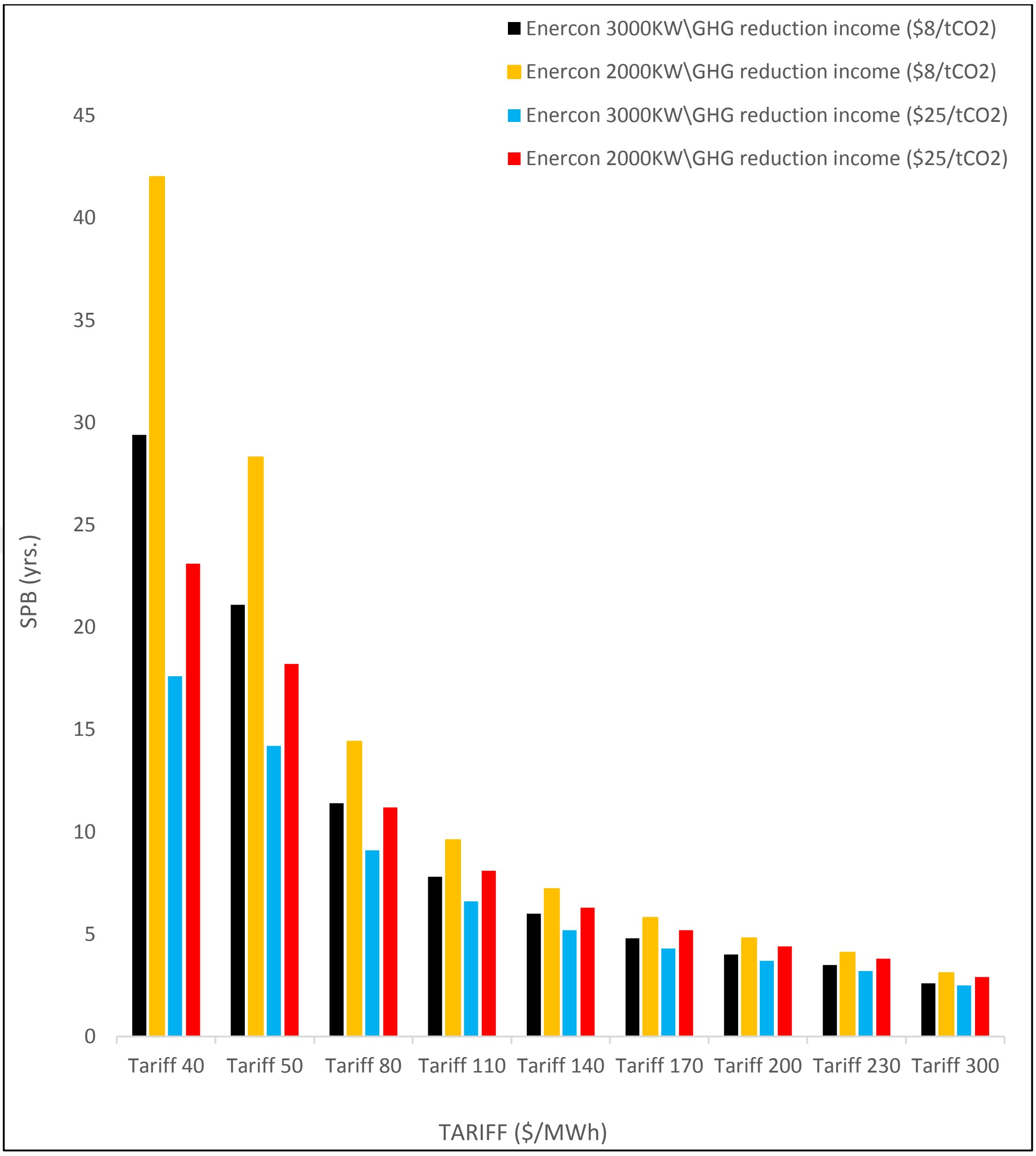

Figure 4.39: SPB with tariffs by effect all GHG reduction income for all Enercon (3000, 2000) kW projects at the Al-Amarah site / grant 1

4.10.2 Evaluation of Projects by Calculating Net Present Value (NPV) Versus Tariffs with Effects on GHG Reduction Income

The Table 4.18 illustrates the calculations of NPV versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Amarah site, where we note a gradual rise in the NPV value with increased tariffs, as shown in Figure 4.40 and Fig. 4.41.

Table 4.18: NPV versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Al-Amarah site

Tariff ($/MWh)	NPV ($)			
	Wind project Enercon-3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$
40	–81,324,913	–58,854,092	–134,786,596	–106,416,442
50	–68,533,539	–46,062,717	–118,637,063	–90,266,909
80	–30,159,414	–7,688,593	–70,188,465	–41,818,311
110	8,214,710	30,685,532	–21,739,867	6,630,287
140	46,588,834	69,059,656	26,708,731	55,078,885
170	84,962,958	107,433,780	75,157,329	103,527,483
200	123,337,082	145,807,904	123,605,927	151,976,081
230	161,711,207	184,182,028	172,054,525	200,424,679
300	251,250,830	273,721,652	285,101,253	313,471,407

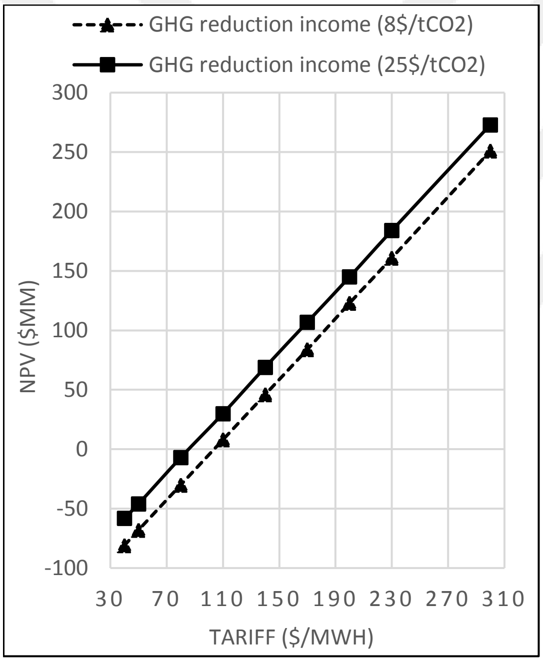

Figure 4.40: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Amarah site/ grant 1

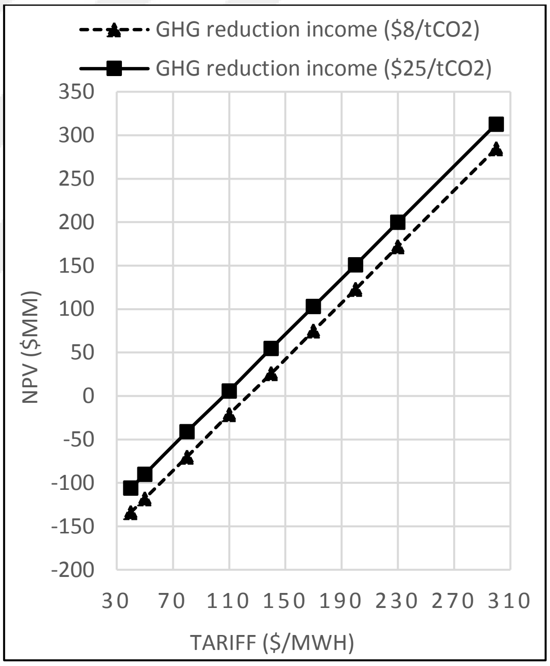

Figure 4.41: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Amarah site/ grant 1

4.10.3 Evaluation of Projects by Calculating Annual Life Cycle Saving (ALCS) Versus Tariffs with The Effects on GHG Reduction Income

Table 4.19 illustrates the calculations of ALCS versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Al-Amarah site, where we note a gradual rise in the ALCS value with increased tariffs, as shown in Figure 4.42 and Fig. 4.43.

Table 4.19: ALCS versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Al-Amarah site

Tariff ($/MWh)	ALCS ($/yr.)			
	Wind project Enercon-3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income $8/t$CO_2$	GHG reduction income $25/t$CO_2$	GHG reduction income $8/t$CO_2$	GHG reduction income $25/t$CO_2$
40	–8,959,409	–6,483,842	–14,849,179	–11,723,694
50	–7,550,208	–5,074,641	–13,070,017	–9,944,531
80	–3,322,605	–847,037	–7,732,528	–4,607,043
110	904,999	3,380,566	–2,395,039	730,446
140	5,132,602	7,608,169	2,942,449	6,067,935
170	9,360,205	11,835,772	8,279,938	11,405,423
200	13,587,809	16,063,376	13,617,427	16,742,912
230	17,815,412	20,290,979	18,954,915	22,080,400
300	27,679,820	30,155,387	31,409,055	34,534,541

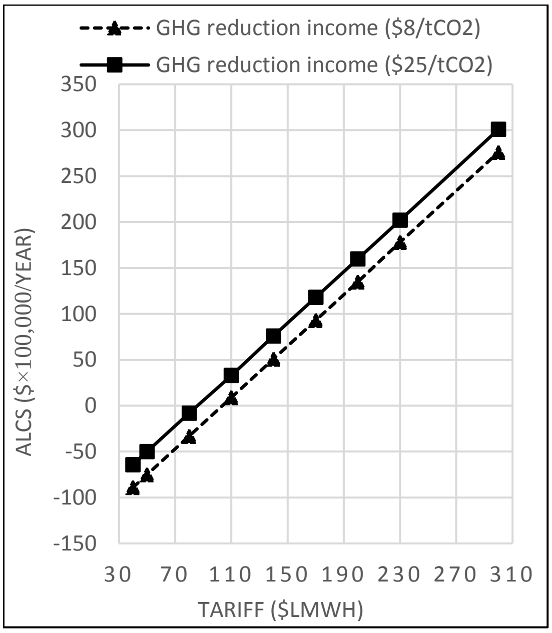

Figure 4.42: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Al-Amarah site/ grant 1

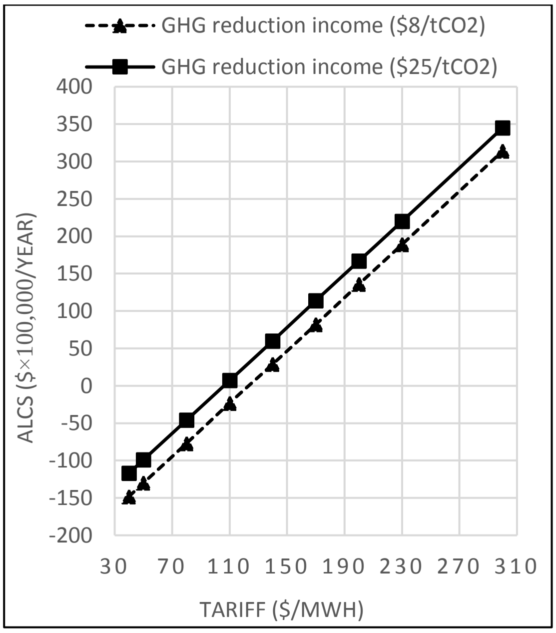

Figure 4.43: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Al-Amarah site/ grant 1

4.11 Mandali Site (Financial / GHG Income)

4.11.1 Evaluation of Projects by Calculating a Simple Payback Period (SPB) Versus Tariffs with Effects on GHG Reduction Income

Table 4.20 illustrates the calculations of SPB versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Mandali site, where we note a drop in SPB with increased tariffs, as shown in Figure 4.44 and Fig. 4.45.

Table 4.20: SPB versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Mandali site

Tariff ($/MWh)	SPB (yrs.)			
	Wind project Enercon- 3000 kW/25 unit		Wind project Enercon- 2000 kW/38 unit	
	GHG reduction income $8/tCO$_2$	GHG reduction income $25/tCO$_2$	GHG reduction income $8/tCO$_2$	GHG reduction income $25/tCO$_2$
40	39.2	22.1	57.4	28.8
50	26.9	17.6	36.3	22.3
80	13.9	10.9	17.3	13.3
110	9.4	7.9	11.3	9.5
140	7.1	6.2	8.4	7.4
170	5.7	5.1	6.7	6
200	4.7	4.3	5.6	5.1
230	4.1	3.8	4.8	4.4
300	3.1	2.9	3.6	3.4

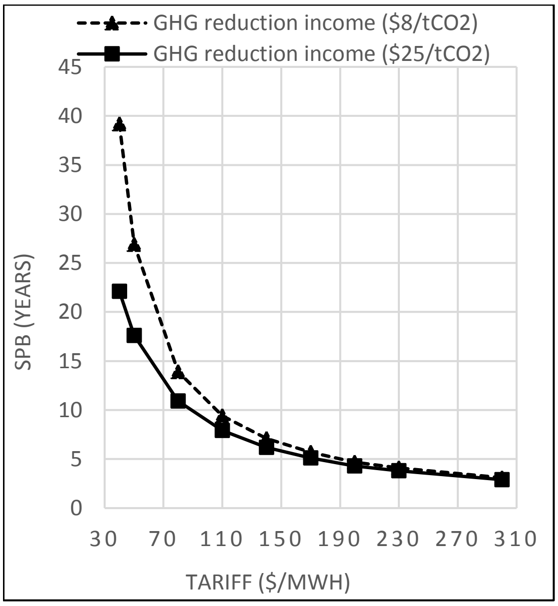

Figure 4.44: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Mandali site/ grant 1

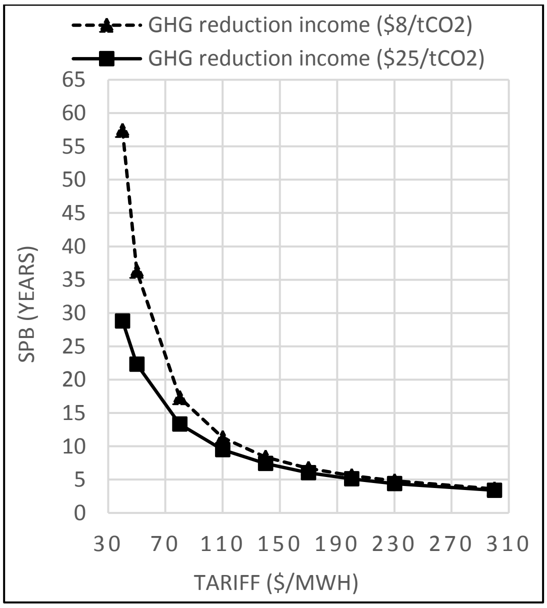

Figure 4.45: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Mandali site/ grant 1

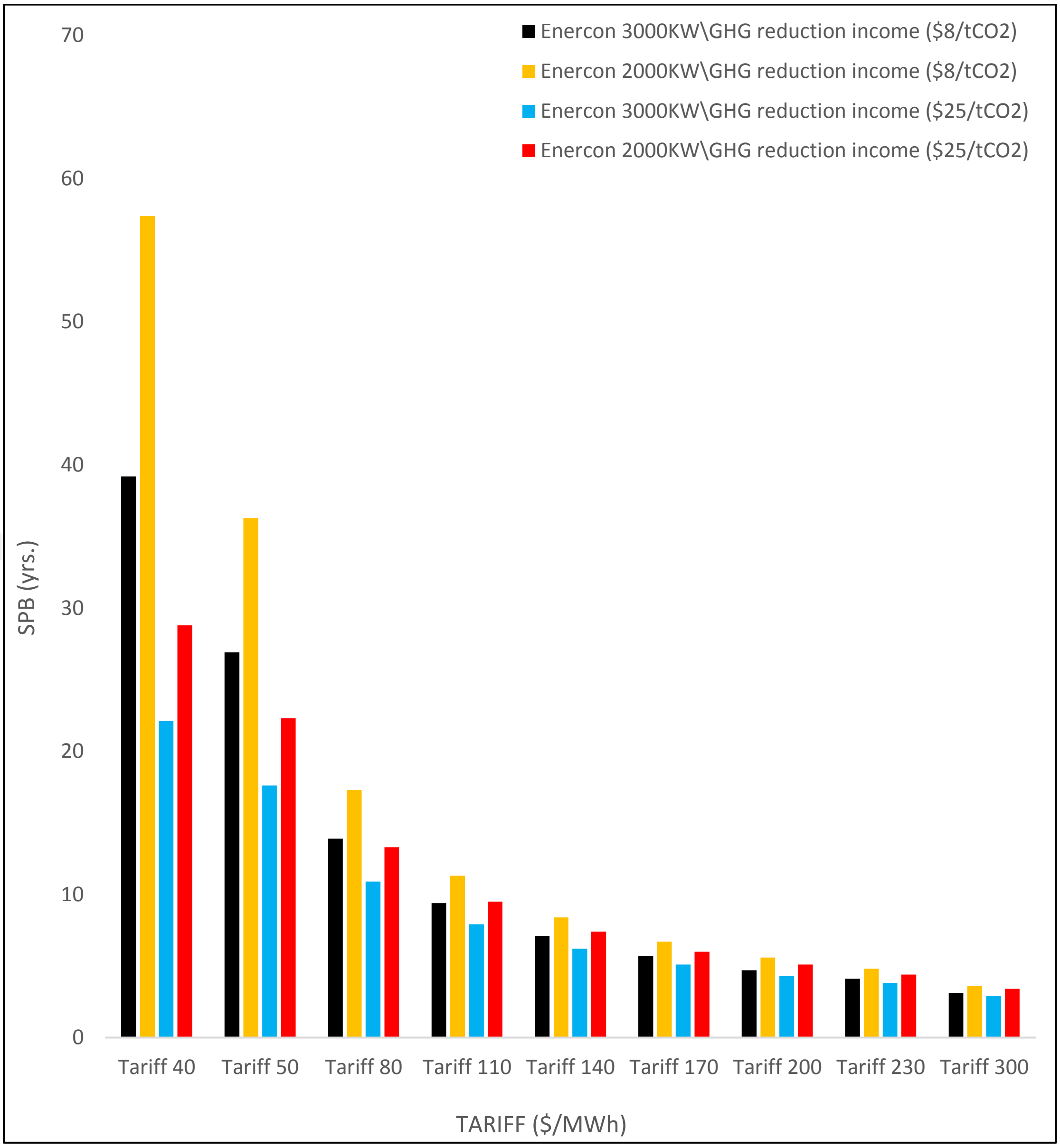

Figure 4.46: SPB with tariffs by effect all GHG reduction income for all Enercon (3000, 2000) kW projects at the Mandali site/ grant 1

4.11.2 Evaluation of Projects by Calculating Net Present Value (NPV) Versus Tariffs with Effects on GHG Reduction Income

The Table 4.21 illustrates the calculations of NPV versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Mandali site, where we note a gradual rise in the NPV value with increased tariffs, as shown in Figure 4.47 and Fig. 4.48.

Table 4.21: NPV versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Mandali site

Tariff ($/MWh)	NPV ($)			
	Wind project Enercon- 3000 KW/25 unit of turbine		Wind project Enercon- 2000 KW/38 unit of turbine	
	GHG reduction income (8$/t$CO_2$)	GHG reduction income (25$/t$CO_2$)	GHG reduction income (8$/t$CO_2$)	GHG reduction income (25$/t$CO_2$)
40	-89,510,868	-70,019,397	-143,874,703	-118,812,247
50	-78,415,470	-58,923,999	-129,608,057	-104,545,600
80	-45,129,277	-25,637,806	-86,808,117	-61,745,660
110	-11,843,083	7,648,388	-44,008,177	-18,945,720
140	21,443,111	40,934,582	-1,208,237	23,854,220
170	54,729,304	74,220,775	41,591,703	66,654,160
200	88,015,498	107,506,969	84,391,643	109,454,100
230	121,301,692	140,793,163	127,191,583	152,254,039
300	198,969,477	218,460,948	227,058,109	252,120,566

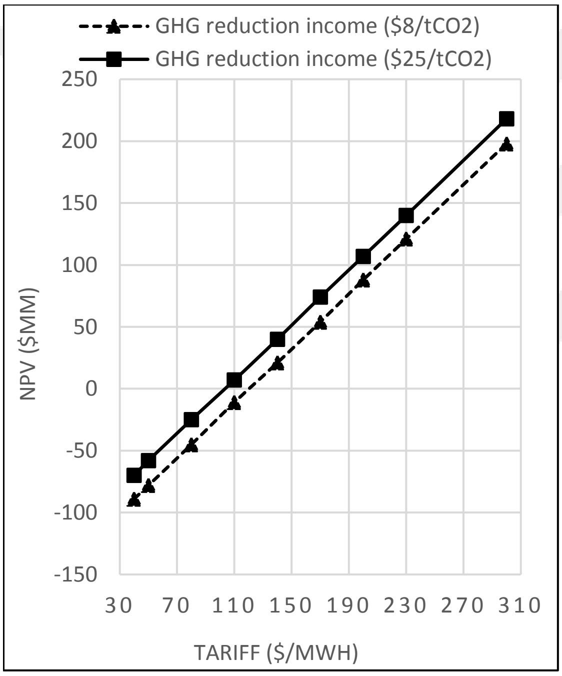

Figure 4.47: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Mandali site/ grant 1

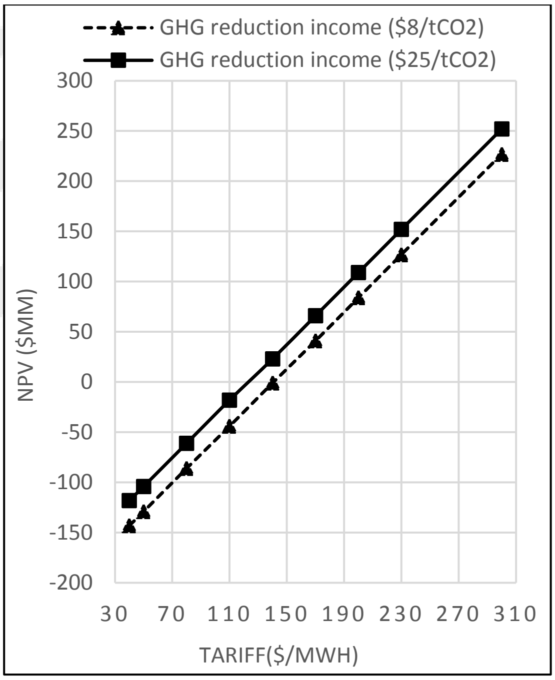

Figure 4.48: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Mandali site/ grant 1

4.11.3 Evaluation of Projects by Calculating Annual Life Cycle Saving (ALCS) Versus Tariffs with The Effects on GHG Reduction Income

Table 4.22 illustrates the calculations of ALCS versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Mandali site, where we note a gradual rise in the ALCS value with increased tariffs, as shown in Figure 4.49 and Fig. 4.50.

Table 4.22: ALCS versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Mandali site

Tariff ($/MWh)	ALCS ($/yr.)			
	Wind project Enercon- 3000 KW/25 unit of turbine		Wind project Enercon- 2000 KW/38 unit of turbine	
	GHG reduction income (8$/t$CO_2$)	GHG reduction income (25$/t$CO_2$)	GHG reduction income (8$/t$CO_2$)	GHG reduction income (25$/t$CO_2$)
40	-9,861,240	-7,713,902	-15,850,399	-13,089,316
50	-8,638,881	-6,491,543	-14,278,670	-11,517,587
80	-4,971,805	-2,824,468	-9,563,483	-6,802,400
110	-1,304, 730	842,608	-4,848,296	-2,087,213
140	2,362,346	4,509,684	-133,109	2,627,973
170	6,029,422	8,176,760	4,582,078	7,343,160
200	9,696,498	11,843,836	9,297,265	12,058,347
230	13,363,574	15,510,911	14,012,451	16,773,534
300	21,920,084	24,067,421	25,014,554	27,775,637

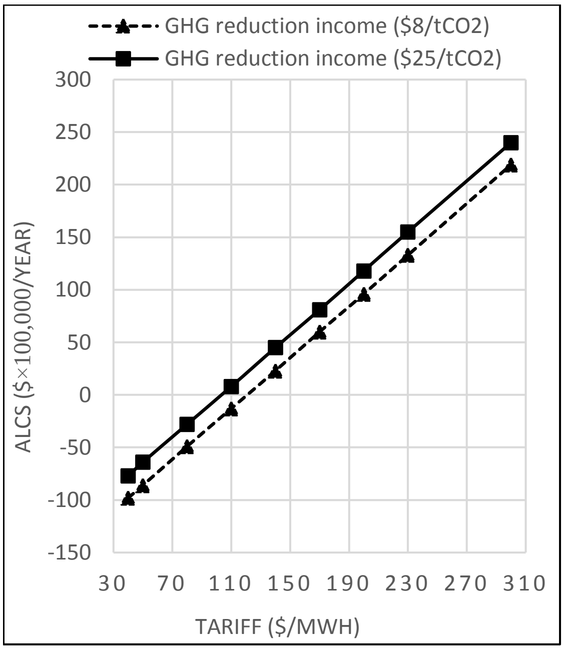

Figure 4.49: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Mandali site/ grant 1

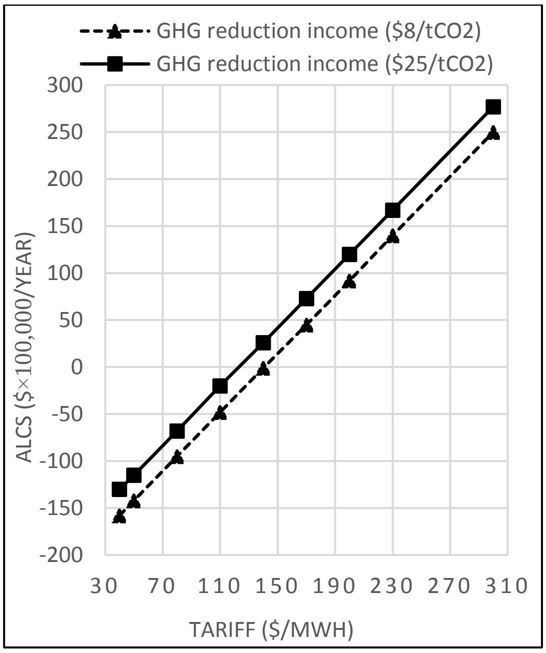

Figure 4.50: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Mandali site/ grant 1

4.12 Samarra Site (Financial / GHG Income)

4.12.1 Evaluation of Projects by Calculating a Simple Payback Period (SPB) Versus Tariffs with The Effects on GHG Reduction Income

Table 4.23 illustrates the calculations of SPB versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Samarra site, where we note a drop in SPB with increased tariffs, as shown in Figure 4.51 and Fig. 4.52.

Table 4.23: SPB versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Samarra site

Tariff ($/MWh)	SPB (yrs.)			
	Wind project Enercon- 3000 kW/25 unit		Wind project Enercon- 2000 kW/38 unit	
	GHG reduction income $8/tCO$_2$	GHG reduction income $25/tCO$_2$	GHG reduction income $8/tCO$_2$	GHG reduction income $25/tCO$_2$
40	54.5	28.1	84.2	36.8
50	35.1	21.9	48	27.7
80	17	13.1	20.9	15.9
110	11.2	9.4	13.4	11.1
140	8.4	7.3	9.8	8.6
170	6.7	6	7.8	7
200	5.5	5.1	6.4	5.9
230	4.7	4.4	5.5	5.1
300	3.6	3.3	4.1	3.8

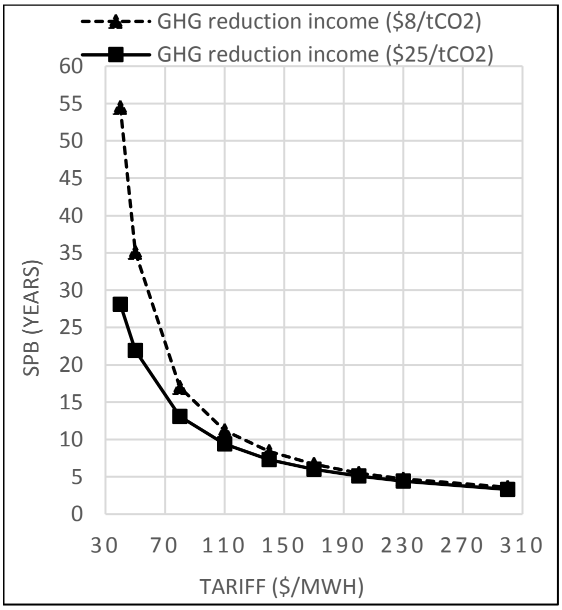

Figure 4.51: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Samarra site/ grant 1

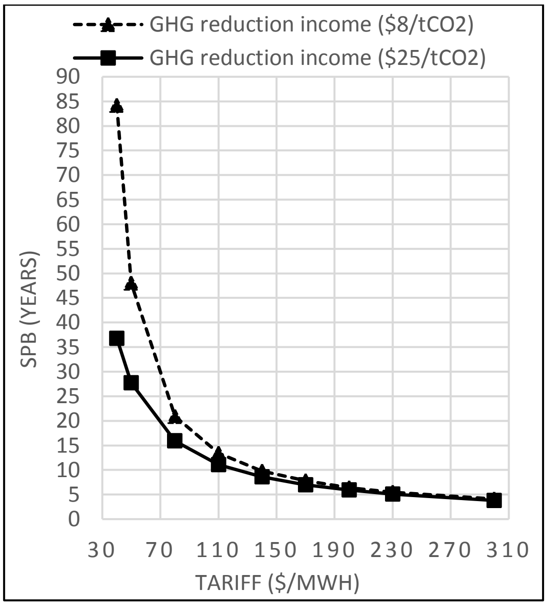

Figure 4.52: SPB versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Samarra site/ grant 1

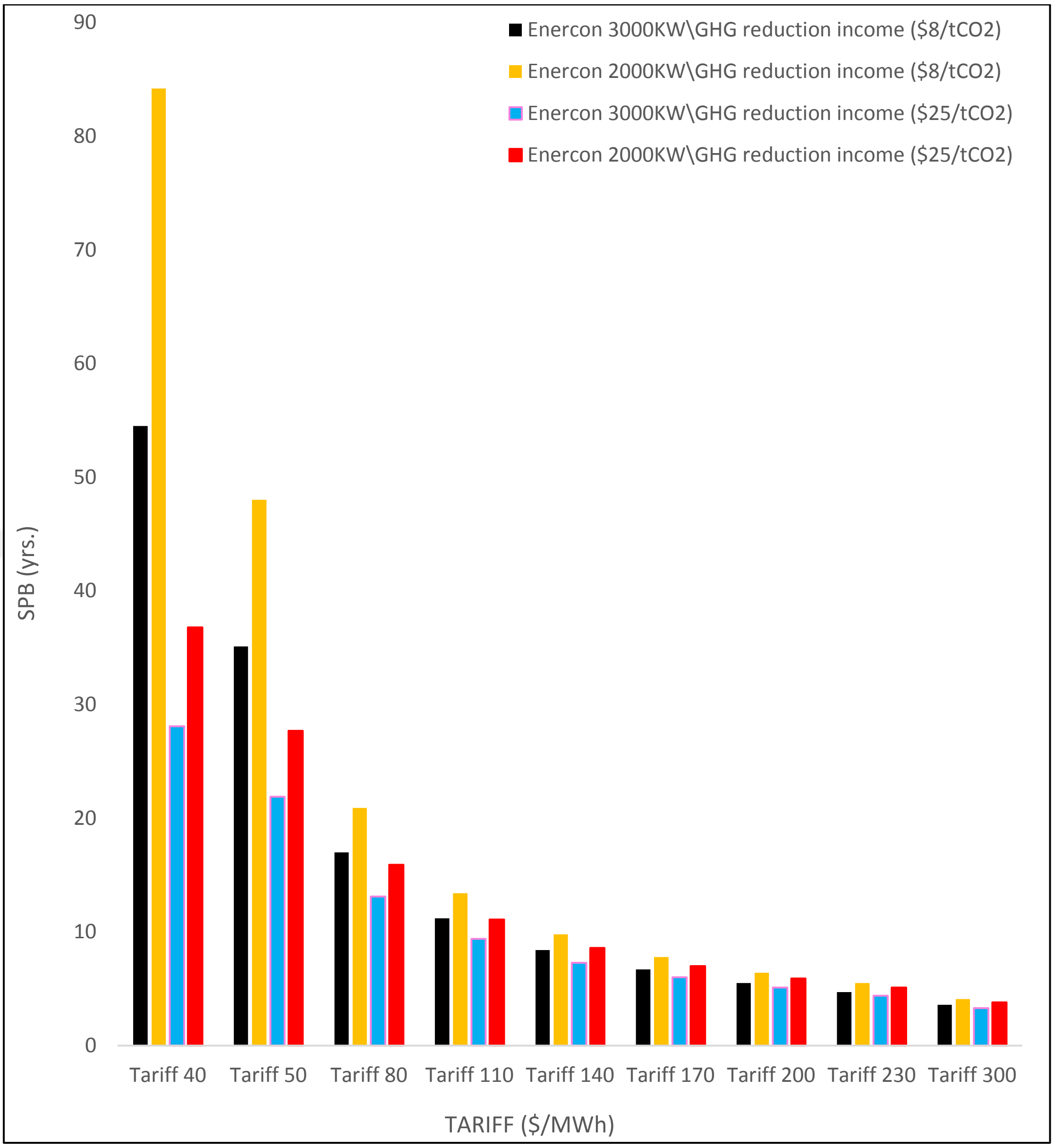

Figure 4.53: SPB with tariff by effect all GHG reduction income all Enercon (3000, 2000) kW projects at the Samarra site/ grant 1

4.12.2 Evaluation of Projects by Calculating Net Present Value (NPV) Versus Tariffs with The Effects on GHG Reduction Income

The Table 4.24 illustrates the calculations of NPV versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Samarra site, where we note a gradual rise in the NPV value with increased tariffs, as shown in Figure 4.54 and Fig. 4.55.

Table 4.24: NPV versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Samarra site

Tariff ($/MWh)	NPV ($)			
	Wind project Enercon-3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$	GHG reduction income $8/tCO_2$	GHG reduction income $25/tCO_2$
40	-96,372,620	-79,378,544	-151,716,581	-129,508,246
50	-86,698,848	-69,704,773	-139,074,625	-116,866,290
80	-57,677,535	-40,683,459	-101,148,757	-78,940,422
110	-28,656,221	-11,662,146	-63,222,889	-41,014,554
140	365,092	17,359,168	-25,297,021	-3,088,686
170	29,386,406	46,380,482	12,628,847	34,837,182
200	58,407,720	75,401,795	50,554,715	727,63,050
230	87,429,033	104,423,109	88,480,583	110,688,919
300	155,145,432	172,139,508	176,974,275	199,182,611

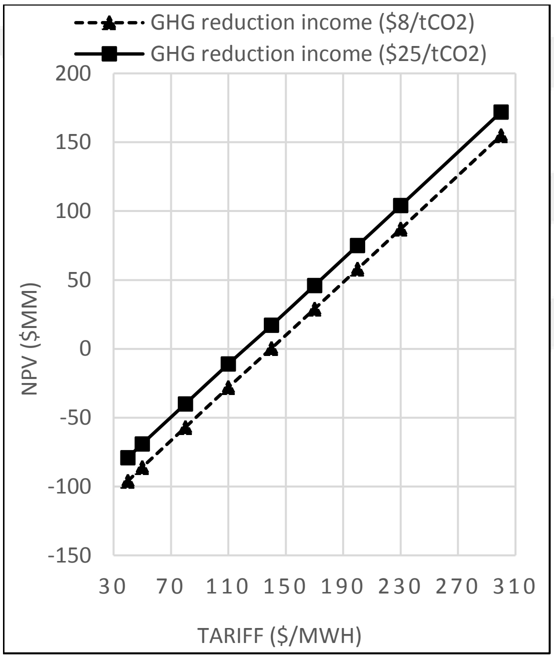

Figure 4.54: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Samarra site/ grant 1

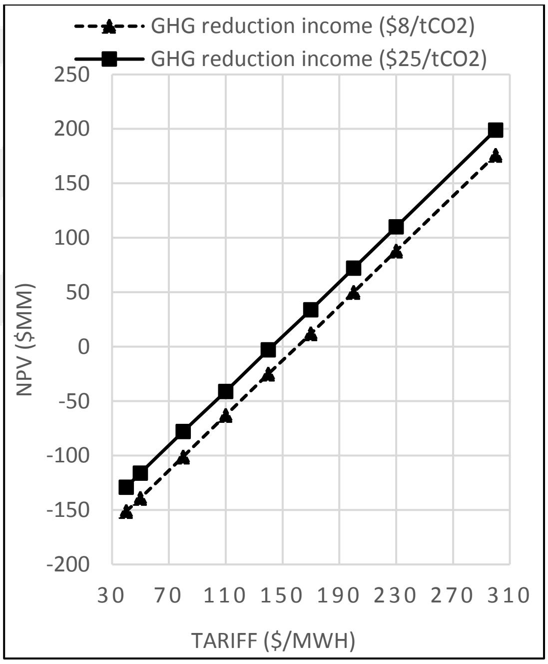

Figure 4.55: NPV versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Samarra site/ grant 1

4.12.3 Evaluation of Projects by Calculating Annual Life Cycle Saving (ALCS) Versus Tariffs with The Effects on GHG Reduction Income

Table 4.25 illustrates the calculations of ALCS versus Tariffs showing the effects on GHG reduction income for projects using the Enercon E82-(3000, 2000) kW wind turbines with the RETScreen program at the Samarra site, where we note a gradual rise in the ALCS value with increased tariffs, as shown in Figures (4.56, 4.57).

Table 4.25: ALCS versus Tariffs showing the effects on GHG reduction income for 75MW wind project at the Samarra site

Tariff ($/MWh)	ALCS ($/yr.)			
	Wind project Enercon-3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income $8/t$CO_2$	GHG reduction income $25/t$CO_2$	GHG reduction income $8/t$CO_2$	GHG reduction income $25/t$CO_2$
40	-10,617,186	-8,744,981	-16,714,323	-14,267,674
50	-9,551,445	-7,679,240	-15,321,583	-12,874,934
80	-6,354,223	-4,482,018	-11,143,364	-8,696,714
110	-3,157,001	-1,284,796	-6,965,144	-4,518,494
140	40,222	1,912,426	-2,786,924	-340,275
170	3,237,444	5,109,648	1,391,296	3,837,945
200	6,434,666	8,306,870	5,569,515	8,016,165
230	9,631,888	11,504,093	9,747,735	12,194,385
300	17,092,073	18,964,278	19,496,915	21,943,564

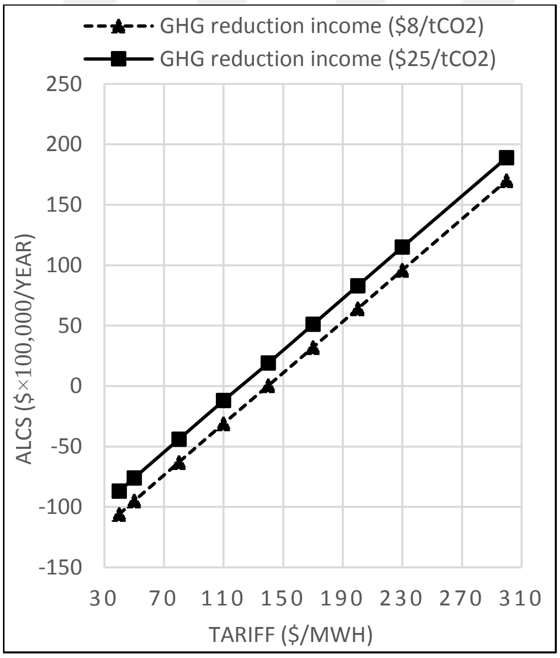

Figure 4.56: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E3-3000 kW turbine at the Samarra site/ grant 1

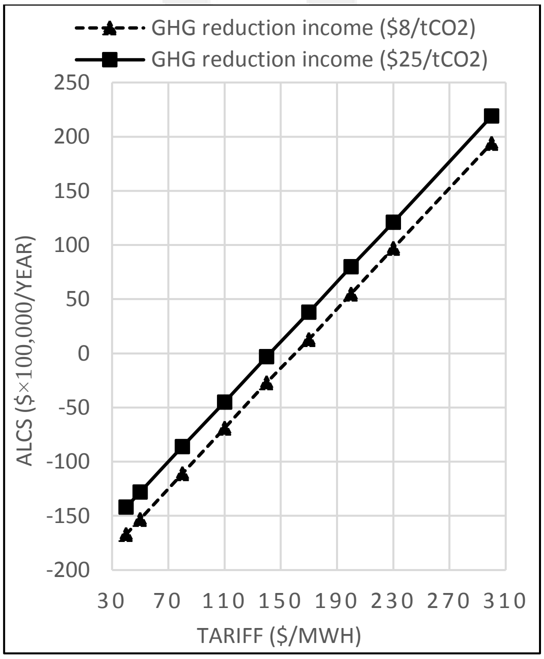

Figure 4.57: ALCS versus Tariffs showing the effects on GHG reduction income for the 75MW wind project with the Enercon-E82-E2-2000 kW turbine at the Samarra site/ grant 1

4.13 Financial Summary

1- Table 4.26 illustrates minimum feed-in tariffs with simple payback less than 25 years (project life) with effect grants (Grant 1, Grant 2, Grant 3) \GHG income ($\$0/tCO_2$).

Table 4.26: Minimum feed-in tariffs for simple payback below 25 years (project life) for selected sites at grants (Grant 1, Grant 2, Grant 3) \GHG income ($0/tCO2)

Site	Minimum Tariff ($/MWh)					
	Wind project Enercon-3000 kW/25 unit turbine			Wind project Enercon-2000 kW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
Al-Nasiriyah	48.5	40	32	58	51	44
Al-Amarah	54	44.5	35	64	56	49
Mandali	62	51.5	40	72.3	64	55.5
Samarra	71	59.2	46.4	81	71.2	62.6

2- Table 4.27 illustrates the minimum feed-in tariffs with a simple payback less than 25 years (project life) with an effect on the GHG income ($\$8/tCO_2$, $\$25/tCO_2$) \ grant 1.

Table 4.27: Minimum feed-in tariffs for simple payback below 25 years (project life) for selected sites at GHG income ($8/tCO2, $25/tCO2) \ grant 1

Site	Minimum Tariff ($/MWh)			
	Wind project Enercon- 3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income $\$8/tCO_2$	GHG reduction income $\$25/tCO_2$	GHG reduction income $\$8/tCO_2$	GHG reduction income $\$25/tCO_2$
Al-Nasiriyah	40.3	23.5	50	33
Al-Amarah	46	28.7	55.8	38.3
Mandali	54	37	64	47.3
Samarra	63	46	73.8	56.3

3- Table 4.28 illustrates the tariffs for the wind power project with a 25-year lifetime to be financially viable (NPV≥0) by effect grant (Grant 1, Grant 2, Grant 3) \GHG income ($0/t$CO_2$).

Table 4.28: Financially viable (NPV≥0) by effect grant (Grant 1, Grant 2, Grant 3) \GHG income ($0/t$CO_2$)

Site	Viable Tariff ($/MWh)					
	Wind project Enercon- 3000 kW/25 unit turbine			Wind project Enercon-2000 kW/38 unit turbine		
	Grant 1	Grant 2	Grant 3	Grant 1	Grant 2	Grant 3
Al-Nasiriyah	101	79	57	121	103	85
Al-Amarah	113	88	63.5	132.4	113	93.5
Mandali	130	101.5	73	150	128	106
Samarra	149	117	84.3	169.3	144.4	119.4

4- Table 4.29 illustrates the tariffs for the wind power project with a 25-year lifetime to be financially viable (NPV≥0) by effecting the GHG income ($8/t$CO_2$, $25/t$CO_2$) \ grant 1.

Table 4.29: Financially viable (NPV≥0) by effect GHG income ($8/t$CO_2$, $25/t$CO_2$) \ grant 1

Site	Viable Tariff ($/MWh)			
	Wind project Enercon-3000 kW/25 unit turbine		Wind project Enercon-2000 kW/38 unit turbine	
	GHG reduction income ($8/t$CO_2$)	GHG reduction income ($25/t$CO_2$)	GHG reduction income ($8/t$CO_2$)	GHG reduction income ($25/t$CO_2$)
Al-Nasiriyah	92.8	75.2	112.3	94.7
Al-Amarah	104	86.6	123.8	106.3
Mandali	121.2	103.7	141.3	123.8
Samarra	140.2	122.7	160.5	160.5

CHAPTER FIVE

CONCLUSION

1- Advantage to Iraq site of being of the Sedimentary plains and It has a flat surface, which leads to a rapid movement of the winds.

2- The selection of four research sites distributed in each area of Iraq, which included sites in Nasiriyah and Amarah in southern Iraq, Mandali in the central region and Samarra in northern Iraq as these locations have the highest levels of wind speed.

3- The RETScreen program was selected as it is a comprehensive program that works to analyze all technical and financial aspects, and specializes in working on renewable energies.

4- Technical analysis shows the following:

- The losses (array losses, airfoil losses and miscellaneous losses) have an impact on the annual production of electrical power for wind farms, where the increase in those losses leads to a reduction of produced energy.
- The availability and number of units also has an impact on the annual production of electrical power for wind farms, where the increase leads to an increase in the energy produced.
- According to the Energy Law, $P = ½ \times \rho \times A \times V^3$, the energy depends on the cubed speed, which leads to an increase in the productive energy as the wind speed increases, Therefore, the Al-Nasiriyah site recorded the highest rate of energy production as it scored the highest rate of accelerated wind. The results of the Al-Amarah, Mandali and Samarra sites followed in descending order.
- The hub height 138 meters is best for wind project as it achieved the highest rate of production of electrical energy compared with other heights (78, 85, 98 and108 meters) due to the wind speed increasing with increasing height, where the annual electricity exported to grid was 156,644 MWh , 140,920 MWh , 122,236 MWh, 106,574 MWh for wind project Enercon-E3-3000 kW-138 meters at the Al-Nasiriyah, Al-Amarah, Mandali and Samarra sites, respectively, while the annual electricity exported to the grid

was 194,909 MWh, 177,916 MWh , 157,173 MWh, 139,274 MWh for the Enercon-E2- 2000 kW-138-meter wind project at the Al-Nasiriyah, Al-Amarah, Mandali and Samarra sites, respectively.

- Greenhouse gas analysis: increased value of Net annual GHG emission reduction tCO_2 rise with increased energy produced from each site with values of 157089 tCO_2, 141320 tCO_2, 122583 tCO_2, and 106876 tCO_2 for the wind project Enercon-E3-3000 kW-138m at Al-Nasiriyah, Al-Amarah, Mandali and Samarra sites respectively, while the values were 195462 tCO_2, 178421 tCO_2, 157619 tCO_2, and 139669 tCO_2 for the wind project Enercon-E2-2000 kW-138-meter at the Al-Nasiriyah, Al-Amarah, Mandali and Samarra sites, respectively.

5- With regard to the wind project at 75 MW, we note an increase of the occupied area by the wind station when the turbine type used in the project where the occupied area by wind farm (Enercon-E3-3000 kW\25 unit) is equivalent to 5,100,000 m^2 while the area occupied by the wind farm (Enercon-E2-2000 kW\38 unit) is equivalent to 9,460,000 m^2.

6- Cost analysis shows the following:

- The initial cost increases with a decrease of power capacity per unit turbine because of the increases in number of turbines for the same wind farm with a 75MW capacity, where the initial costs are $105,226,776 and $155,221,413 for the wind project Enercon-E3-3000 kW-138-meter and wind project Enercon-E2-2000 kW-138 meter, respectively.
- O&M Annual costs also increase with turbine type for the reason mentioned in the point above where O&M costs are $3,187,500 and $4,845,000 for wind project Enercon-E3-3000 kW-138 meters and wind project Enercon-E2-2000 kW-138 meters, respectively.

7- The financial analysis shows the following:

Financial functions {Simple Payback Period (SPB), Net Present Value (NPV), Annual Life Cycle Saving (ALCS)} are the criteria to determine the appropriate tariff for the project in proportion to the project life. These are the criteria to accept the project when it becomes financially viable.

8- Advantages and disadvantages of using the Enercon wind turbine E3- 82-3000 kW versus the Enercon wind turbine E2-82- 2000 kW for wind projects 75 MW.

- Advantages:

A decrease in the number of units, the initial costs, the O&M annual costs, the Simple Payback Period and the time period to construction and erection of the plant and occupied area of the wind farm) and an increase (in the net present value, annual life cycle saving and IRR).

- Disadvantages:

A decrease in (the annual electricity exported to the grid, the capacity factor, net annual GHG emission reduction tCO_2).

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