PAN-AFRICAN UNIVERSITY
INSTITUTE FOR WATER AND ENERGY SCIENCES
(including CLIMATE CHANGE)

Master Dissertation

Submitted in partial fulfillment of the requirements for the Master degree in

ENERGY POLICY TRACK

Presented by

Mahamat Bichara ISSAK

Analyzing the cost of electricity for solarPV- diesel hybrid generation for sub-regional hospital electrification in Dourbali district, Chad.

Defended on 04/09/2018 Before the Following Committee:

Chair:	Dr. Souhila Bensmaine	Professor at University Tlemcen
Supervisor:	Dr. Wojciech Budzianowski	Consulting Services Wroclaw Poland
External examiner:	Dr. Nana Sarfo Agyemang Derkyi	Professor at university of Ghana
Internal examiner:	Dr. Abdellah Benyoucef	Energy coordinator at PAUWES

Academic year: 2017-2018

DECLARATION

I, MAHAMAT BICHARA ISSAK, hereby declare that this thesis represents my personal work, realized to the best of my knowledge. I also declare that all information, material and results from other works presented here, have been fully cited and referenced in accordance with the academic rules and ethics.

Signature: ____________________ Date: __01/08/2018___________________

MAHAMAT BICHARA ISSAK

Certification

I undersigned, **Prof. Dr. Wojciech Budzianowski** lecturer at the Pan African university, institute of water and energy sciences including climate change (PAUWES), certify that **MAHAMAT BICHARA ISSAK** conducting this master thesis under my supervision.

Signature: ____ ____ Date: __01/08/2018__________

DEDICATION

This dissertation is dedicated to my parents, my brother Yassine Bichara Issak.

ACKNOWLEDGEMENT

First, I thank Allah Almighty for has given me the strength to achieve this modest work. Thanks, my mom and Dad for their precious and efficiency advices.

I acknowledge with thanks to African union commission and the PAUWES for awarding me the scholarship to advance my career. I thank the university of Tlemcen and Algerian government for the hospitality we got from. Thanks also all the sponsor of the PAUWES project in particular, GIZ, BMZ, KFD, DAAD. Thanks to all my professor teach me in PAUWES and specially my supervisor prof. Dr. Wojciech Budzianowski for he has help me in shaping this topic and writing this thesis report.

Thanks to all PAUWES staffs and the managers specially to the executive Director prof. Abdullatif Zerga as well as the deputy director prof. Chewki Ziani-Cherfi.

I would like to thank the Director of Ader-Tchad Mr. Badour Adam Badour and also the deputy director for their precious help during my internship and help me for the data.

Abstract

Promoting electricity access in rural and peri-urban areas is a common challenge all over the world. The lack of reliable caring in the rural health district, caused by poorly preserved pharmaceutical products that is due to the lack of sustainable electricity.

Therefore, this study is mainly analyzed the costs (LCOE, NPC) of electricity for solar PV associated with setting up a hybrid solar PV / diesel generation system for supply the electricity to sub-regional hospital of Dourbali.

The daily total load of the hospital determined is 11.05 KW. The solar irradiation resources of the site determine with the NASA database is average of 5.83 KWh/m^2. The hospital energy demand varies according to the season, the peak months are March, April, Mai, Jun.

The result of simulation and optimization of the Homer pro of the system show the PV system and its storage battery respectively with capacity of 14.1 KW and 59.1 KWh, the battery has a battery life of 14.7 hours with an estimated service life of 11 years. The total capital cost of the system is $74.363; the system net present cost is $ 148,511 and the levelized cost of electricity is $ 0.544. The return on investment is 15.2% and the repayment time is 7.5 years.

The economic analysis and the solar resource, it is concluded that this system is very profitable and favorable with the rural portfolio throughout the sub-region. With the reduction of fuel consumption, reduced hours of work of the diesel generator, the emission of CO2 and the energy production share by source 77% of electricity generated from the renewable source and 23% from the diesel, this hybrid system is economically and environmentally sustainable. Finally, this study is an opportunity for the government and the national electricity company and the institutions that contribute to rural development to invest heavily in this sustainable energy to meet the challenge.

Indeed, these optimized results from Homer are in accordance with the results made by other researchers in the same hybrid system.

Résumé

Promouvoir l'accès à l'électricité dans le milieu rural et péri-urbain est un défi commun partout le monde. Le manque de soin de qualité dans le district sanitaire rural, causé par mal conservations de produits pharmaceutique qui est due par la carence de l'électricité permanente et durable. De ce fait, cette étude principalement a pour objectif d'analysé les couts (LCOE, NPC) de l'électricité pour le PV solaire associé à la mise en place d'un system génération hybride solaire PV/diesel pour l'approvisionnement d'électricité de l'hôpital sous-régional de Dourbali.

La charge totale quotidienne de l'hôpital déterminée est de 11,05 kW. Les ressources d'irradiation solaire du site déterminées avec la base de données de la NASA est en moyenne de 5,83 KWh / m2. La demande énergétique de l'hôpital subrégional de Dourbali varie selon la saison, les mois de pointe sont mars, avril, mai et juin.

Le résultat de la simulation et de l'optimisation du système Homer pro montre que le système PV et sa batterie de stockage ont respectivement une capacité de 14,1 kW et 59,1 kWh, la batterie a une autonomie de 14,7 heures avec une durée de vie estimée à 11 ans. Le coût en capital total du système est de $74,363; Le coût net actuel du système est de $148 511 dollars et le coût moyen actualisé de l'électricité est de $0,544 dollar. Le retour sur investissement est de 15,2% et le délai de remboursement est de 7,5 ans.

L'analyse économique et la ressource solaire concluent que ce système est très rentable et favorable au portefeuille rural dans toute la sous-région. Avec la réduction de la consommation de carburant, la réduction des heures de travail du générateur diesel, l'émission de CO_2 et la part de production d'énergie à la source 77% de l'électricité produite à partir de la source renouvelable et 23% du diesel, ce système hybride est économique et environnemental durable. Enfin, cette étude est une opportunité pour le gouvernement, la compagnie nationale d'électricité et les institutions qui contribuent au développement rural d'investir massivement dans cette énergie durable pour relever le défi.

En effet, ces résultats optimisés d'Homère sont conformes aux résultats obtenus par d'autres chercheurs du même système hybride.

TABLE OF CONTENTS

List of Tables

List of Figures

Abbreviations and Acronyms

RE	Renewable energy
SHS	Solar home system
RETs	Renewables energies technologies
LCOE	Levelized cost electricity
NPC	Net present cost
AC	Alternative current
DC	Direct current
Ader-Tchad	Agency for renewables energies development of Chad
SNE	National company of electricity
EROI	Energy return on investment
KW	kilowatt
KWh	Kilowatt hour
KWh/d	Kilowatt hour per day
KWh/yr	Kilowatt hour per year
HOMER	Hybrid optimization model for electric renewables
PV	photovoltaic
$	Dollar US
F cfa	Chad national currency
PPA	Power purchase agreement
IRR	Internal rate of return
MW	Mega-watt
L	litter
NGO	No-governmental organization
Fit	Feed-in-tariff
UNDP	United nations development program
IRENA	International renewable energy agency
IEA	International energy agency

CHAPITER I: GENERAL INTRODUCTION

I. Introduction

Population growth, progress in technological development and the modernization of human society are exploding the world's energy needs. Added to global warming caused by the emission of greenhouse gases caused by industrialization, we realize that it is necessary to find alternative solutions to meet the need while safeguarding our holy environment.

Electricity is an increasingly essential resource in remote health facilities as well as other educational sectors and food security. Therefore, the world needs renewable alternatives to achieve energy needs.

The sun is a major source of inexhaustible free energy for the planet Earth. However, new technologies are being employed to generate electricity from harvested solar energy. Solar energy approaches have been proven and are widely practiced throughout the world as renewable alternatives. Thereby, the development of novel solar power technologies is considered to be one of many key solutions toward fulfilling a worldwide increasing of energy (Kabir, et al., 2018). Approximately four (4) million exajoules (10^{18}J) of solar energy reaches the earth annually.

The African continent is endowed with large renewable energy potential, varying in type across diverse geographic areas. Solar resources are most abundant everywhere. North Africa and some parts of Sub-Saharan Africa (SSA) especially Sahel region enjoy particularly long sunny days with a high intensity of irradiation. Sahelian and Tropical conditions also feature strong solar irradiation (IRENA, 2015). Since 2009 to 2016 solar energy costs have been reduced, solar PV now offers a rapid, cost-effective pathway to providing modern energy services to the approximately 600 million Africans who lack access to electricity and utility-scale electricity for the grid (IRENA, 2016).

I.1 Problem statement

Due to the challenges facing the electricity generation in Chad, we came up with the idea of Solar PV generation might be the best alternative solution instead of diesel power generation for peri-urban electrification. Because the peoples live far from national grid don't have electricity access, by the way, they use mini generator for producing electricity. It has too much cost (operating & maintenance, diesel transport cost, risk of diesel penury, etc.). Chad has the lowest electricity access in the whole region of Sahel countries, estimated at 7% whole country, 14% for urban and less than 0.1% for rural areas (Ader-Tchad, 2016). Thereby, the peri-urban area where there is no grid access. However, there are no studies that show peoples' sense of ownership and/or acceptability, interest and readiness on the technology transfer and their understanding of the benefits of such technology in their livelihood transformation process. It is the aim of this study to fill this gap in literature and set the basis upon which the stability of electricity access of the Sahel peri-urban and rural community. So, this study can make understand to Chad government and local people how the technology transfer and solar energy project installation can be guaranteed and saving the bill of diesel.

I.2 Objective of the Study

1. General objective:

The main aim of this study is to analyze the cost of electricity (LCOE, NPC) associated with setting up solar PV/diesel hybrid generation for supply sub-regional hospital of Dourbali. in order to reduce the consumption of diesel fuel, the working hours of diesel generators, as well as the cost from fuel bills.

2. Specifics Objectives:

1) To estimate the everyday load demand of Dourbali sub-regional hospital.
2) To Simulate and optimize the solar PV/diesel hybrid system with HOMER software application.
3) To compare the Levelized costs of electricity (LCOE) of solar PV and solar-diesel hybrid generation,

I.3 Research Questions

- What is the everyday load demand of Dourbali sub-regional hospital?
- Could LCOE provide a better alternative for the electrification of the Dourbali sub regional hospital?

- Which electricity generator is more sustainable?

I.4 Relevance of the study

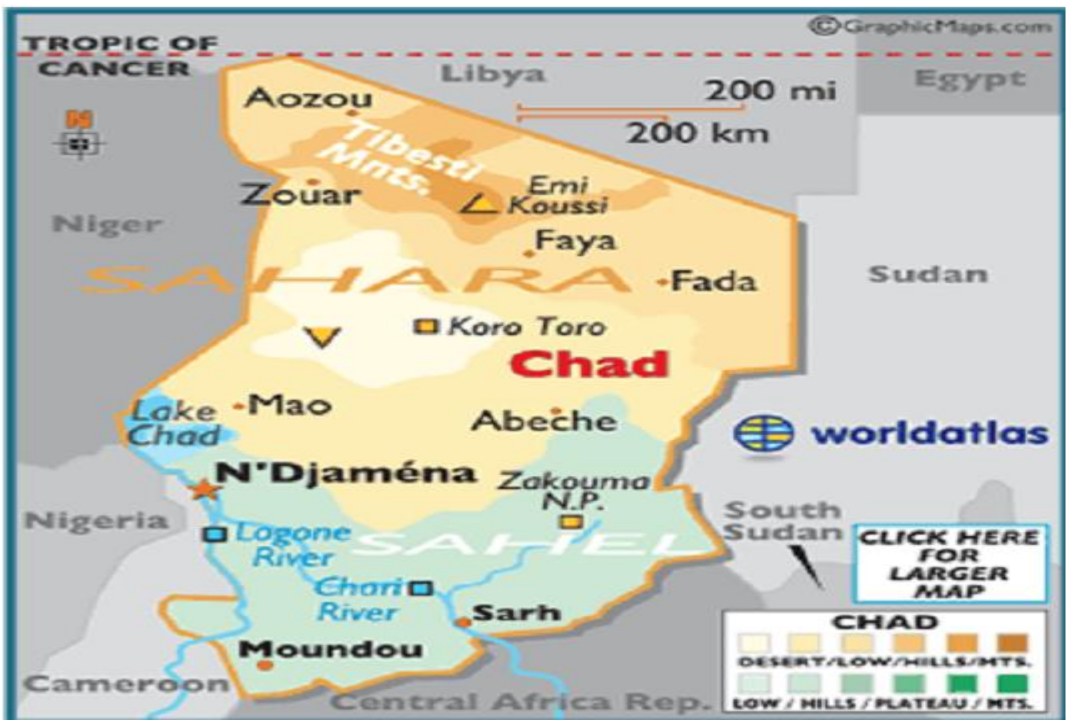
the results of this study may trigger the use of solar energy in Chad especially peri-urban inhabitants who do not have access the national grid electricity. These findings could be that the cost of electricity generated by solar PV is much reliable than that by diesel engine generate. Furthermore, this could reduce CO2 emission, boost the small business economy. As solar PV cost decrease gradually over the time, that community could beneficiate permeant electricity for their needs in public services (hospital, school, mosque, public administration).

I.5 Scope of the study

The study analyzed the costs of Photovoltaic solar energy electrification versus solar-diesel hybrid generation on the rural and peri-urban community in Dourbali district, Chad. The locality was purposely selected because its strategic position and socio-economic city, excellent solar resource, population growth.

I.6 Background of the study

At 1,284,000 square kilometers, Chad is the world's 21st-largest country. Chad is the fifth largest country in Africa after Sudan, Algeria, the Democratic Republic of Congo and Libya. Chad is in north central Africa, lying between latitudes 7° and 24°N, and 13° and 24°E.



Source : http://www.worldatlas.com/county/afrique/Chad

figure I 1: geographic map of Chad

Chad's national statistical agency projected the country's 2015 population between 13,630,252 and 13,679,203, with 13,670,084 as its medium projection; based on the medium projection, 3,212,470 people lived in urban areas and 10,457,614 people lived in rural areas. Chad is plagued by situations of fragility, including: a difficult climatic environment; economic and financial vulnerability; a poor social inclusion system; and for several years, persistent hotspots of conflict along its borders. The country's one major abiding challenge is to resolve these various situations of fragility in order to efficiently combat poverty and preserve its social cohesion. To attain this objective, it is crucial to: address infrastructural constraints, especially in the transport and energy sectors; ensure greater integration into the sub-regional economy; achieve significant progress in governance, especially at the sector and local level; and build an attractive environment for business development.

This research was inspired by the gaps in the electricity access and renewable resources exploitation in Dourbali district, Chad.

I.7 Energies Resources in Chad

The energy potentials of a country are natural resources that the country possesses destined to produce electricity or the modern energy these potentials can renewable beings called clean or non-renewable energy called fossil energies (pollutants).

3. Fossil fuel resources

i. Oil

The fossil natural resources existing in Chad are poorly exploited except for black gold. This latter potential has already been confirmed by the exploitation of the Doba Basin since 2003 (MEPTCHAD, 2013). The country has 7 oil basins, but only the Doba basin is in operation with several fields in production. January 2004 was placed at 900 million barrels (140,000,000 m3), with production in 2003 at 36,000 barrels per day (5,700 m3 / d). Added that of Bongor since 2011 and by the existence of oil field Sédigui, in the region of Lake Chad. The export of crude oil is transported by an oil pipeline linking the Doba deposit to the port of Kribi in Cameroon was commissioned in 2003 to allow the export of production. Its capacity is 250,000 bbl / d (13 Mt / yr.) and its cost was $ 3.7 GUS (Richard, 2013). In 2011, the Chinese company CNPC (China National Petroleum Consortium) began operating the koudalou field in the Bousso department, which is then refined to the Djermaya national refinery in northern N'Djamena; With a production capacity of 20,000 bbl/d which could be increased thereafter. It can produce 700,000 t of gasoline and kerosene, 20,000 t of diesel and 60,000 t of LPG per year (Richard,2013).

ii. Natural gas

The country is very poor on the potential of natural gas, according to the report of the international energy agency mentioning in the "Africa Energy Outlook 2014" that the natural gas resources of Chad are estimated at the end of 2013 about 0.3 trillion cubic meters. As a result, unfortunately the production remains zero. (IEA, Africa energy outlook, 2014).

4. Renewable energy Resources

Renewable resources are energy potentials covering topics of proven technical and economic importance around the world. Energy supplies from renewable energies (such as solar, thermal, photovoltaic, wind, hydroelectric, biofuels, waves, tides, oceanic and geothermal sources) are essential components of each country's energy strategy, particularly because of concerns about environment and for sustainability (Weir, 2006). Chad is one of the countries with the best operating climates of renewable energies. According to the International Forum on renewable energies in N'Djamena in February 2012, Chad has significant potential in renewable energy including solar, hydroelectric, wind / wind, biomass.

iii. Solar resource

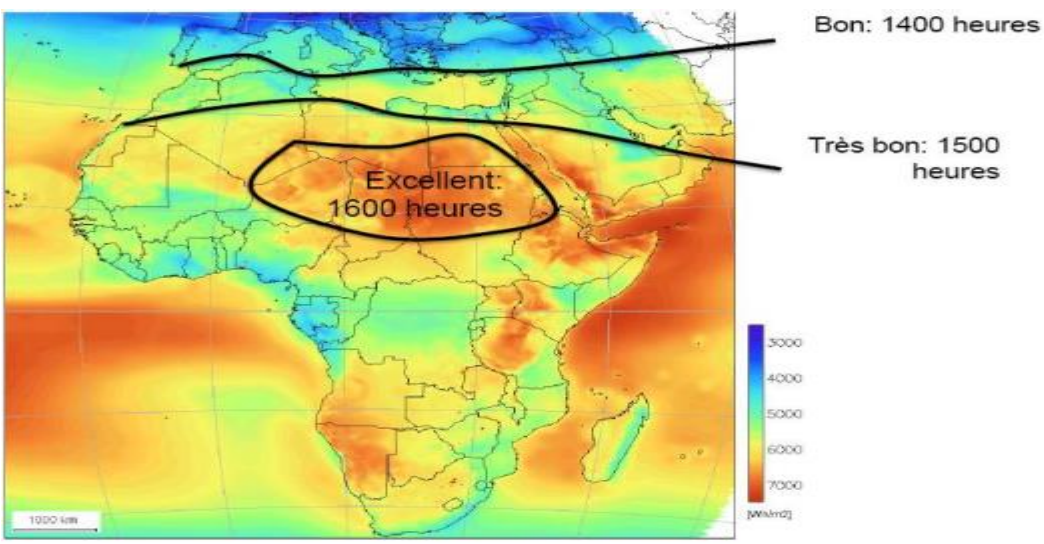


figure I 2: solar irradiation in the continent and Chad

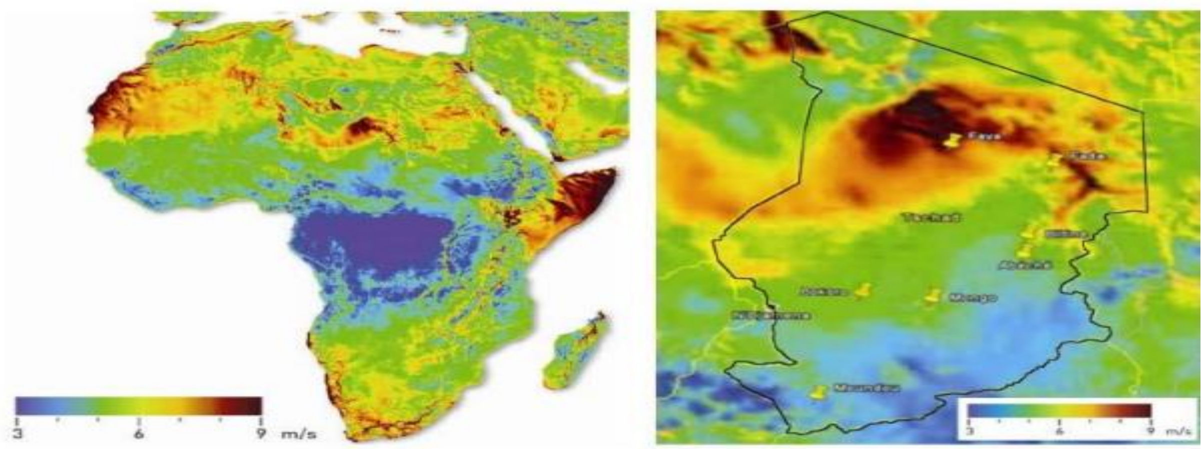
Source: (Richard, 2013)

Chad is one of the sunniest countries on the African continent. From the north to the south of the country, the sun shines from 2 750 to 3250 hours a year. Which gives an average of 4 to 6 kilowatt per square meter per day.

iv. Wind resource

Wind energy is wind energy that is mechanically and kinetically transformed by turbine blades and rotors. This potentiality is used either directly for pumping water or producing clean electricity without harming the environment.

Researchers have shown that Chad has significant wind fields, particularly in the central and northern regions. With an average density of 6m / s in the center and 7-9m / s in the northern regions and more important on the plateaus and the top of the Ennedi (Richard, 2013). The practical work carried out on the city of Ndjamena by the researchers (Abdraman, 2016) and his colleagues showed important results. The average wind speed of about 3.5m / s can turn a turbine with a 30-meter diameter rotor and produce a capacity of 1.8 MW.



Source : www.3tier.com/en/support/resource-maps

figure I 3: wind resource dispatching in Africa and Chad

v. Hydropower resource

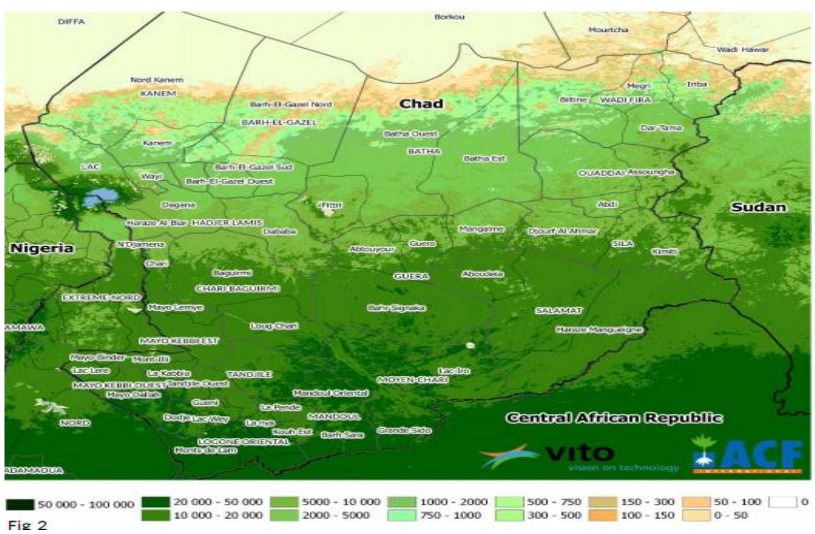
Despite the absence of offenders, the country has permanent water resources such as Batha, Goré, Baibokoum and thus with the greatest fall in hydroelectric production. This site is the waterfall called "Gauthiot Falls" located in the southern part of the country, in the department of Lake-Léré. These sites can be used to produce mini-turbine electricity to power small communities and contribute to rural electrification projects.

Source: AFREC, 2012

figure I 4: Gauthiot Falls site

vi. Biomass Resource

Chad has good potential for biomass energy in tropical forest areas with vegetarian materials used to produce electricity and also biofuel. This natural resource is also found in the Sahelian zone. The situation of biomass production in Chad is typical of the region, with overall surplus production but masking deficit areas at the local level. For pastoral and agro-pastoral areas, in the east, production is largely favorable. On the northern pastoral fringe, in Borkou, deficits are observed in areas characterized by typically very low production (production of less than 50 kg/ha) (ACF, 2016).



Source: AFREC, 2016

figure I 5: Total dispatching map of Biomass resource in Chad

vii. Geothermal resource

Geothermal energy, which comes from the energy of the Earth, has long been known by man and exploited by him. Its use goes back to antiquity (Weir, 2006). Thus, the latter is classified by non-polluting energies called renewable. Its production has not started yet in Chad but has resources. In general, the zones far from the tectonic plate boundaries have a geothermal gradient (temperature increase as a function of depth) of the order of 25 ° C30 ° C per km of depth. These values do not allow the use of this energy to produce electricity economically because the drilling would need to be several kilometers deep (MEPTCHAD, 2013).

I.8 Current electricity status in Chad

Since a long time, the country crosses heavy energy crisis, it is classified among the country the badly fed by electricity of the continent. The total electricity generation capacity is around 232 MW in 2015, of which 120 MW for oil fields of ESSO supply also the city of komé, 20 MW from Djarmaya refinery to supply national grid of SNE and 70 MW for the rest of the country (including 64 MW in Ndjamena). However, in 2016, the Chad National Electricity Company (SNE-Chad) provides the capital Ndjamena with 120 MW on the local network only city of N'Djamena. But the National Electricity Company (SNE) holds all the installations. The power available is 110 MW and less than 50% of the installed capacity is available for reasons of obsolescence and lack of maintenance.
This power generated by the thermal power plant installed in the west side of the capital; It works by fossil fuel precisely by diesel. As for 1995, the total installed net capacity of power plants, the fuel around the 29 MW, now, the country did not develop energy sector. Overall, the population's access to electricity was 6% at the national level. At present, with the inauguration of a new Ndjamena thermal power station, the rate is increasing at the capital level. Rural electrification of about 0.1% (IEA, 2014 a).

Electricity generate from renewable sources it is too negligible, there to many micro-installations of solar PV in suburban and the remote areas. Most of this installation an off-grid system for small business owners and solar home system. Thereby, government recently has installed some micro-grid of solar PV for rural electrification via National Agency for renewable energy development ADER. ADER installed three solar PV micro-grids with power capacity of 44.64KW, 39.60KW, and 36.72 Respectively DOUGUIYA, MOMBO, GUELENDEN. See the figure below.

Recently in June 2018, the Chadian State inaugurated the mini-wind farm in Amjaraz, Eastern Ennedi region, the total capacity of power is 1.1 MW. So, from that, Chad is considered as wind energy producer country.

Table I. 1: The total installed power in Chad from different sources:

Sources:	Capacity (MW)
Diesel (thermal)	210
solar	0.121
wind	1.1

I.9 Electricity market in Chad

The electricity market in Chad is going through an economic and financial crisis since 1968 until 2006 during which the price is 83 fcfa between 0 to 30 kwh, the rate of electricity has changed only once, important efforts are being made to electrify the whole country where electricity is expensive and rare. in August 2012, a decree of the Ministry of Trade and Industry set new tariffs for electricity produced and distributed by the National Electricity Company (SNE). For low voltage domestic use, the kWh is $0.155 (local currency: 85 F CFA) for the first tranche (from 0 to 150 kWh) and $0.23 (125F CFA) for the second tranche (more than 150 kWh).

For the power source, there is a single slice which is $0.23, (125 F CFA) per kWh. Similarly, public lighting has a single slice and is worth $0.23, (125 F CFA) per kWh. The medium voltage, with single slice also, is $0.23KWh, (125 F CFA / kWh). The preferential rate costs $0.23KWh, (125 F CFA / kWh) for full hours; $0.155/KWh (85 F CFA / kWh) peak and off-peak hours. The penalties are $87.87/KVA (48, 330 F CFA / kVA) overtaking. These tariffs, applicable throughout the national territory, are subject to change after evaluation during a year, says the ministerial decree that prevents any violation of its provisions will be punishable by law No. 30 of 28 November 1968 on prices, economic intervention and the repression of economic offenses (SNE-TCHAD, 2012).

The new electricity tariffs in Chad are below the old tariffs. For example, well before the new pricing, the 0 to 60 kWh range cost $0.155/KWh (83 F CFA / kWh; that of more than $0.11/KWh to $0.136/KWh (60 to 197 FCFA / kWh). According to Mahamat Senoussi Cherif, director general of the National Electricity Company (SNE), even a Chadian, who earns a salary below the guaranteed minimum interprofessional $109 per month (60,000 F CFA per month), can easily access electricity.

Insecurity in the national grid pushed the government has taken this drastic step to reduce by 37% the cost of electricity consumption, not only to allow access to the entire population to energy, but also to fight against fraud ",

Fraudulent connections on the lines in the capital account for around 80% of electricity consumption. To reduce the rate of fraud, SNE wants to popularize the use of the prepaid counter.

But even reduced by 37%, prices on electricity in Chad are still expensive, compared to those practiced in neighboring countries. In Cameroon, for example, the price of domestic consumption is $0.09/KWh (50 F CFA / kWh), if the monthly consumption does not exceed 110 kWh. Beyond 110 kWh, the price of the kilowatt goes from $0.127 to $0.143 (70 F CFA to 79 F CFA).
noted that the tariff before 2006 are accompanied by the VAT tax as follows consumption 30khw VAT 11%, 60kwh VAT 15%, 120kwh VAT 18%.

Table I. 2: The new electricity tariffs produced and distributed by SNE throughout the national territory

Basse tension			
Domestic uses	1st tranche: from 0 to 150 KWh	85 FCFA/KWh	$0.155/KWh
	2nd tranche: from 0 to 150 KWh	125 FCFA/KWh	$0.23/KWh
Big customers	1st tranche: from 0 to 150 KWh	85 FCFA/KWh	$0.155/KWh
	2nd tranche: more than 150 KWh	125 FCFA/KWh	$0.23/KWh
Motor force	Single tranche	125 FCFA/KWh	$0.23/KWh
Public lighting	Single tranche	125 FCFA/KWh	$0.23/KWh
Medium voltage			
Single tranche		125 FCFA/KWh	$0.23/KWh
Preferential tariff	Full hours	125 FCFA/KWh	$0.23/KWh
	Peak hours	85 FCFA/KWh	$0.155/KWh
	Off-peak hours	85 FCFA/KWh	$0.155/KWh
Fixed premiums	8.055 FCFA / KVA subscribed ($0.015/KVA)		
penalties	48,330 FCFA/ KVA overflows ($87.87/KVA)		

I.10 Energy Policy Perspective and Regulation in Chad

In its quest to find sustainable solutions to energy problems, the Government of the Republic of Chad has developed a reference document that sets out the road to the establishment of a permanent energy planning system in Chad. The "Master Plan for Energy" contains relevant resolutions, decisions and actions to be implemented during the current five-year term of the Head of State. A new Electricity Code is being drafted with the creation of the Regulatory Body for the Electricity Sector (EU-Chad, 2008). According to Chad minister of energy and petroleum (Minister, 2008) Key legislation relating to the upstream hydrocarbons sector includes law No.006/PR/2007 dated 20 April 2007 on hydrocarbons, as amended and supplemented by ordinance No. 001/PR/2010 dated 30 September 2010 approving a model production sharing contract regulating the activities of exploration and production of liquid or gaseous hydrocarbons in the Republic of Chad (together, the Petroleum Law) and decree No. 796/PR/PM/MPE/2010 dated 30 September 2010 implementing the Petroleum Law (together with the Petroleum Law, the Petroleum Legislation). The key institutions involved in the upstream petroleum sector include the government (through the Minister of Energy and Petroleum (MEP)), the National Assembly and the national hydrocarbons company named Société des Hydrocarbures du Chad (SHT). According to the Petroleum Law, hydrocarbons in their natural state are vested in the Republic of Chad.

A National Commission for the Negotiation of Petroleum Contracts (NCNPC) was created by decree No. 0015/PR/PM/MP/2007 dated 3 January 2008. The NCNPC is chaired by the MEP and members include the general manager of SHT. Its role is to negotiate, on behalf of the Republic of Chad, the upstream (and downstream) petroleum contracts to be entered into by the Republic of Chad. SHT was established by law No. 27/PR/2006 dated 23 August 2006. SHT is placed under the supervision of the MEP. SHT's mandate is to implement the industrial and commercial policies of the Republic of Chad in the hydrocarbons sector, principally through the following activities:

- prospecting, exploration, development,
- Production and transportation of hydrocarbons; refining, transportation, stocking and
- distribution of petroleum products; and trading of hydrocarbons and
- Petroleum products.

In respect of upstream petroleum operations, SHT is granted a number of rights under the Petroleum Law, including the right in any petroleum contract to an option, following a declaration of commercial discovery, to acquire a percentage interest in the rights and obligations under the petroleum contract.

Add recently, a National Agency for renewable energy development (ADER) was created under law N°009/PR/2O13 in August 19, 2013? It is a public institution of industrial and commercial character endowed with a legal personality and independent of its management. By the way, this agency has a vision to develop renewable energy sustainable for future through many projects of rural electrification inprogress.

CHAPTER II: LITERATURE REVIEW

II. Introduction

In this part of research, we are exploring the reviews of renewable energy for analyzing the costs of solar PV generation and solar- diesel hybrid system. This literature obtained from text books, journals, internet and documents from Ministry energy and petrol of Chad and also National agency of development of renewable energy (ADRER-Thad). The cost of electricity for solar PV in Africa studied in IRENA reports. So, let's see the different costs of solar PV in Sub Sahara Africa and particularly, Chad.

II.1 Overview of Solar Photovoltaic Cost

Over recent decades PV has made remarkable progress in reducing costs. It was only a few years ago that PV electricity was four to five times more expensive than fossil fuels. Consequently, it comes closer and may quickly to achieve grid parity in sunny regions. In other less sunny regions with further cost reduction grid parity may be achieved shortly after 2020. Nevertheless, today solar PV is often already competitive for peak power production, for generation in grid-constrained areas, and for many off-grid applications.

The cost of the electricity generated by a PV system is determined by the capital cost (CAPEX), the discount rate, the variable costs (OPEX), the level of solar irradiation and the efficiency of the solar cells. Of these parameters, the capital cost, the cost of finance and efficiency are the most critical for the total cost of solar PV (IRANA, 2016). For lack of accurate and reliable data on the cost of solar PV power generation technology is a significant barrier to rural electrification. Providing this information will help governments, policy-makers, investors and utilities make informed decisions about the role renewables can play in their power generation mix. According to IRENA, the progress of electricity generation from solar PV has greatly increased, global installed capacity has risen from 0.8 GW in 2000 to 222 GW at the end of 2015.

II.1.1 Solar PV Cost in Africa

Africa, sunniest continent, master of solar resource has small delay comparing to Europe, Asia, and America continent. According to IRENA mentioned in its report (IRANA, 2016) Africa's total cumulative installed capacity of solar PV jumped from around 500 MW in 2013 to around 1 330 MW in 2014 and 2 100 MW at the end of 2015. So, these value show that the total installed capacity has quadrupled at the interval of two years.

The solar PV market recently announced a successful tender results or power purchase agreement (PPA) prices in Mexico (an average of USD 0.045/kWh) and Dubai (USD 0.03/kWh) provide compelling examples of this trend. Thereby, Sub Sahara Africa now has its own example, with Zambia's recent announcement of a contract for solar PV at USD 0.06/kWh under the World Bank's Scaling Solar program. In 2015 Africa had estimated costs of between USD 1.35 and USD 4.1/W, while projects for 2016 and beyond are targeting a narrower range, with the majority of projects between USD 1.4 and USD 3/W. This compares to a global average in 2015 of USD 1.8/W for utility-scale projects. These low-cost structures are being targeted in North African countries including sub-Saharan countries.

There are several types of PV generating systems, where the differences between each technology reside in the yield, the price as well as the material used. Among other things we have mono-crystalline, poly-crystalline and amorphous. So, the performance of a PV system depends strongly on meteorological conditions, such as solar radiation and temperature (Baghdadi, et al., 2018).

II.1.2 Solar PV off-grid

Off-grid solar electric power is a promising technology for remote regions in rural Africa where expansion of the electricity grids is prohibitively expensive (Gunther , et al., 2017). The opportunities for providing clean, sustainable renewable power rapidly to Africa's rural communities via SHS and solar PV mini-grids represents an exciting development opportunity.

An economic assessment of solar PV for rural electrification off-grid system in Sub-Sahara Africa was studied by (Chiemeka , et al., 2016)demonstrate that the feasibility of solar PV off-grid system is highly dependent. So, PV technologies in Sub-Sahara Africa is eligible for project financing as it can repay its loan within the stipulated time considering the current infrastructure and energy policy. The off-grid markets play a vital role in electrifying Africa, as mini-grids can be the most economical solution for remote areas, and the opportunity to deliver a commercially sustainable power supply through solar PV is very large (IRANA, 2016).

According to IRENA and Africa energy outlook the solar home systems and grid-connected rooftop solar PV systems can be implemented in Africa not only in rural areas with large non-electrified areas and populations, but also in grid-connected urban areas, which in sub-Saharan Africa are increasingly suffering from frequent power shortages and outages. SHS and grid-connected rooftop solar can help to reduce pressure on the grid by lightening the load of household and commercial power demand from the national grid, as well as meet the basic energy services of those without access to electricity today. In Africa, soar PV system cost and price are still very higher, in order that markets in SSA remain inefficient on the retail side and SHSs require expensive logistics.

II.1.3 Solar PV on-grid

The solar PV on-grid system, it means connected the power produce to a grid let be using the storage system with batteries or let inject direct to the national grid by using net metering. So, typically grid-connected PV system consists of solar panels, DC–DC converter, MPPT controller inverter and grid connection equipment. It has no energy storage losses since there are no batteries used as it is not a standalone system (AbdelHady, 2017). The technical and economic performance of a combination of 80 kW solar PV-grid connected was investigated by (Muyiwa , 2014) at base case of solar PV cost of $2400/kW and average global solar radiation of 6.0 kWh/m2/day, it was found that this energy system can generates annual electricity of 331,536 kWh with solar PV contributing 40.4% and the Levelized cost of energy is $0.103/kWh. Based on the findings from this study, the development of grid-connected solar PV system in the north-eastern part of Nigeria could be economically viable. The effects of the cost of PV system and global solar radiation were also investigated.

II.1.4 Previous Solar PV-diesel hybrid system study

When we have electric power, system combine more than two different sources for electricity generation it is called Hybrid system. This technology is broadly widespread over the world. In Sub-Sahara Africa, the solar PV –diesel hybrid system used for reducing the diesel costs and the environmental risk. In Ethiopia solar PV hybrid was studied by (Girma*, 2013). Integration of PV systems with the diesel plants is being disseminated worldwide to reduce diesel fuel consumption and to minimize atmospheric pollution and the proposed simulation has been done to assure that the PV-Diesel hybrid system is Economically and technically feasible for Ethiopia as well. The costs of components are taken from the online site of manufacturing and equipment suppliers and adjusted to an Ethiopian price value. Thereby, the simulation shows that solar PV system with Generator backup is more cost effective and environmentally friendly over the conventional diesel generator alone system with in life time of the project.

The performance analysis of hybrid PV/diesel/battery system studied by (Laith , et al., 2017) in Sabah, Malaysia. Their study on two different scenarios based, it showed the impact of injection of PV into mini-grids based on important operational procedures over different RE penetration levels. The system simulation carried out by using Homer software. Therefore, they compare two existing systems in both locations were compared to the optimum sizing of the PV system in order to examine whether the systems are optimally selected prior the installation for the same load profiles, solar radiation and temperature data sets. The effects of changing RE penetration levels on NPC, LCOE and associated technical properties, the influence of different PV penetration levels on the harmful emissions generation were also shown and discussed. After the optimum results, it indicates that the existing systems were not optimally selected prior to installation. So, Hybrid PV/Diesel/Battery system is seen to be the best technical and economic performance compared to the other scenarios, as well as also reporting good economic and environmental performance, which result in increased system sustainability. The 100% Renewable Energy system showed the best environmental characteristics with the highest costs.

II.2 Homer software

HOMER software is a (Hybrid Optimization of Multiple Electric Renewables), the micro-power optimization model, simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications (JONATHAN, 2015). It simulates the operation of a system by making energy balance calculations in each time step of the year. The software compares the electric and thermal demand in each time step to the energy can supply in that time step and calculates the flows of energy to and from each component of the system. Before that, there are too many other software was developed (e.g. HYBRID2, HOGA, HYDOGEMS, RAPSIM, SOMES, SOLSIM, MEAD). Among all of those cited above, HOMER is most used. Due to a variety of technology options and their differences in cost plus energy resource availability. It was developed by National Renewable Energy Laboratory (NREL, 2017).

II.3 Diesel power generation system

A diesel generation is a combination of a diesel engine with an alternator to generate electrical power by using fossil fuel (gasoline). A diesel compression-ignition engine is usually designed to run on diesel fuel or naturel gaze. Diesel engine is the compression-ignition engine make-up story by Rudolf diesel in 1892. and since then our understanding, utilization and demand for the internal combustion engine has continued to grow and evolve within our environment (Hamilton, et al., 2017). Diesel engines have a long history and where only power generator source of supplying urban and remote power generation in Chad. This chapter presents the key characteristics of diesel engine technology that have led to its ubiquitous use in this challenging operating context. It also outlines some of the advantages and disadvantages associated with using diesel fuel for remote power generation.

II.4 Levelized Cost of Electricity (LCOE).

According to (IRENA, 2012) cost can be measured in several different ways, and each way of accounting for the cost of power generation brings its own insights. There are several methods to evaluate the economic viability of distributed generation projects. The capital cost of assets, the operation and maintenance costs, and the fuel costs must be considered in a systematic way so that a comparison can be made. One of the most commonly used metrics is the Levelized cost of electricity (LCOE) (Lai, et al., 2017). This method of cost calculation is providing a comparison of different technologies with different project size, life time, different capital cost, return, risk, and capacities. Generally, the cost of a generating asset or the power system is evaluated by using Levelized cost of electricity (LCOE) (Lai, et al., 2017). The LCOE can be regarded as the minimum cost at which electricity must be sold in order to achieve break-even over the life-time of the project.

The global weighted average LCOE of utility-scale PV plants is estimated to have fallen by 73%

between 2010 and 2017, from around USD 0.36 to USD 0.10/kWh. Between 2010 and 2013, the global weighted average LCOE declined by about 20% per year, although it experienced a more modest 8% decline between 2013 and 2014, as the market experienced a shift away from traditionally low-cost markets towards higher cost markets, such as Japan and the United States (IRENA, 2015). Between 2014 and 2015 the LCOE declined again, by around a fifth, while the descent between 2015-2016 was 11%. The estimated decline between 2016 and 2017 was 15%.

The Levelized cost of energy for solar PV systems is high, at US $0.83 per kWh. With an annual rate of decrease of PV system costs of 4% and 7.67% it is estimated that it will take from 8.7 to 16.9 years for solar home systems for electricity generation to become competitive with conventional diesel generators.

The research done on cost-effectiveness of off-grid PV systems in Indonesia on a provincial level by (Veldhuis, et al., 2015). In this study they calculate cumulative numbers for the nominal power of installed off-grid PV systems, their LCOE and the relative financial benefits compared with diesel generators, which are a common means for electricity generation in remote areas. Results show that the costs of off-grid hybrid PV systems with an average LCOE of 0.38 USD/kWh are 19% cheaper compared with electricity generation by diesel genets in most rural parts of Indonesia. These systems show an average LCOE of 0.76 USD/kWh which is 3% cheaper than stand-alone diesel genets on average.

II.5 Energy Return on Investment (EROI).

Energy return on investment (EROI) is the ratio of energy returned from an energy-gathering activity compared to the energy invested in that process.

(Kittner, et al., 2016) have study the Energy return on investment (EROI) of mini-hydro and solar PV systems designed for a mini-grid, they find that distributed mini-grids with penetrations of solar PV up to 50% of annual generation can exceed the EROI of some fossil-based traditional centralized grid systems. The analysis will help planners and engineers optimize mini-grids for energy payback and utilize local resources in their design. The results suggest higher EROI ratios for mini-hydropower plants than solar PV, though mini-hydropower plants typically yield lower EROI ratios than their large-scale hydropower counterparts.

Energy return on investment is given by the relation below:

$$\boldsymbol{EROI = \frac{Energy\ return\ to\ society}{Energy\ require\ to\ get\ that\ energy}} \qquad (\boldsymbol{eq.1})$$

CHAPITER III: METHODOLOGY FOR REASERCH

III. Introduction

This research uses the concept of LCOE for calculation electricity cost of solar PV and diesel hybrid system. It has been cooperated in current of electricity market from diesel generation. The cost of solar PV investigate breakdown considering module costs and Balance of System Cost. Up to the date costing numbers will retrieve from published sources.

Therefore, the chapter indicates how quantitative data load profile for the sub-regional hospital of Dourbali have been collected, analyzed and interpreted in order to answer the research questions, thereby meeting the purpose of this study. This chapter also comprise the primary and secondary data collections, population sample.

III.1 System design and optimization

Solar PV system design needs collection of all necessary data from NASA resources. A grid modelling in HOMER configured with the actual electricity price in Chad. Storage battery size to supply the load allow to reduce diesel generator operation time. We are adding also some devices as converter from HOMER component database to convert DC/AC load and different system HOMER configuration and simulation.

at the end, analysis of the simulation results and comparison of the levelized cost of electricity (LCOE) with real cost of electricity.

Design PV/Diesel hybrid power system by using the National Renewable Energy Laboratory’s HOMER optimization software, one must provide some inputs such as hourly load profile, monthly solar radiation value for a PV system, the initial cost of each component (renewable energy generators, diesel generators, battery, converter) (Girma*, 2013). this last software allows us to determine the cost of electricity for the solar PV and diesel engine and then for the hybrid system by determining the emission of CO2 on the planet by answering the agreement of Paris cop21. The hourly load data will cover the demand for energy consumption in the hospital.

The primary requirement for the design of the PV-diesel hybrid system is information such as the profile load for the hospital and the life of the electrical appliances. This work will be implemented theoretically and practically on the enclosure of the sub-regional hospital powered by a 100% diesel generator. The steps consist in collecting data on the energy, the quantity and the behavior of the equipment the maximum capacity of the generator. Information on the energy consumption of resident families within the hospital.

At the data collection stage, we had interviewed the hospital staff and noted the power of their usual electrical appliances and the average useful time as well as some patients asking for their opinion on the lack of electricity. Data collected from the sub-regional hospital of Dourbali, a load profile is estimated

Currently there is no policy for emission penalties in Chad but observed the way world people get use REN to save green environment. numerical figures and descriptive information obtained, giving it both a quantitative and qualitative research dimension.

our micro solar power plant system includes a PV field, a storage system (batteries), a converter, and the distribution micro network. and add to the system an electric generator of 90 KVa for hybridism

III.2 Area of study and Study Population

Dourbali is a small city located in the region of Baguirmi, geographically located in 11° 48' 18'' North, 15°51'53''ESAT. Its business is very important. The main economic sources are livestock and agriculture. Its population estimated 17600 in 2012 according to National Institute of Statistic and Economic and demographic of Chad (INSEED-TCHAD, 2012). The sub regional hospital of Dourbali is located in 3km on East side from the town. Thereby, the Dourbali regional hospital has about 30 employees. the hospital staff consists of a regional delegate for public health, a hospital chief physician, an emergency service head, a maternity ward, a service head of the hospital and 15 nurses, 2 guards of the hospital that constantly allow themselves day-night. three drivers. 2 security agents. an accounting manager and his assistance.

the study site is grouped as follows: hospital side consists of different blocks. an administrative office for doctors, a medical examination block as well as the emergency room, laboratory and care rooms, maternity. the other side includes the residence, there are three residences the delegate of public health, hospital management and the chief of doctor.

III.3 Data Collection Methods

Collecting data in Chad is not easy at all. because the secondary data are almost non-existent this is because there was no research in the field of solar energy, these secondary data were collected in different points, with the agency for the development of renewable energies in Chad (Ader-Tchad), scientific articles, reports published by the Chadian state, as well as inquiries made by NGOs. the report by IRENA, NASA, EIA. But concerning the primary it was collected by myself in Dourbali sub-regional hospital. I had a conversation with the hospital's chief doctor several times and interviewed some health workers and patients. Most of my data I got with Ader-Tchad it is the agency which I did my internship.

So, for hospital daily load is determined by energy audit on the hospital, in survey each bloc and room of the hospital.

the collected data of the hospital are reported in table 2. it includes the electrical sightings of the hospital and the household appliances on the residential side. The hospital offers a range of services, including treatment of illnesses, maintenance of injuries and vision of basic immunization services. The latter has sophisticated equipment that requires a reliable power supply.

The energy demand is based on the type and number of medical devices used in the facility, and the frequency with which they are used. Added to the daily demand the add-ons, because some patients come for example with their fan, chargeable torch, etc.

Electricity market data were collected from the SNE (Société nationale d'électrité) archive library.

III.4 Homer data in Put

The data used in this system include the hourly total solar radiation and load data; technical specifications and cost data of diesel generators, photovoltaic modules, power converters and economic parameters, the solar radiation data are downloaded directly from the NASA via Homer pro database. The attitude and longitude kept in precise account of the study site in Dourbali. HOMER simulates the operation of a system by making, the energy balance calculation every hour for each of the 8760 hours in a year.

The price of the equipment and components of the solar field system are used by the manufacturer's standard price and some account for the cost of transport and the customs import tax. All the components of the system used include the hardware and the labor cost of installation. these include the necessary structural support, fasteners, fuses, and safety devices such as the converter, load controller, and so on.

Table III. 1: Estimated the everyday load demand of Dourbali sub-regional hospital

Area	Equipment	Power (w)	Qty	Total Power(W)	Usage hour	On-Time (Time in Use)
Hospital side	CFL light	6O	16	960	5	18h – 23h
	Microscope	20	2	40	5	9h – 14h
	Vaccine Refrigerator/Freezer	60	1	60	24	Ooh – 23h
	Centrifuge	575	1	575	3	11h – 14h
	Refrigerator	90	2	180	24	00h – 23h
	Computers	30	3	90	6	9h – 15h
	Printer	200	1	200	6	9h – 15h
	A. conditioner	1200	2	2400	6	9h – 15h
	Fan	60	3	180	6	9h – 15h
	TV	75	1	75	9	9h – 15h, 18h – 21h
	Add-on	200	-	200	24	0h – 23h
Residency side	CFL light	60	7	42à	3	18h – 21h
	Refrigerator	90	2	180	24	00h – 23h
	A. conditioner	1200	2	2400	12	9h – 15h, 19h – 2h
	TV	75	3	225	8	7h – 8h, 11h – 15h, 18h – 21h
	Fan	60	3	180	12	9h – 15h, 19h – 2h
	Add-on	200	-	200	24	00H – 23h
others	Water pump	1100	1	1100	2	7h – 8h, 14h – 15h
	Outside lamps cfl	60	10	600	12	18h – 6h
Average Hospital daily load				10265		

III.5.1 Daily Load profile

the daily consumption of the selected hospital shows by fluctuations curbs on the fig.III.1 below. Homer, in fact we should expect a lot of fluctuation, depending on the traffic of voice and data. HOMER adds a temporal variability to the load profile in its simulation. The variability has been set in this thesis 10% from day to day, from time-step to time-step and 20%. This results in an average daily load of 2.41 kW (57.81 kWh/day) and a peak of 11.05 kW.

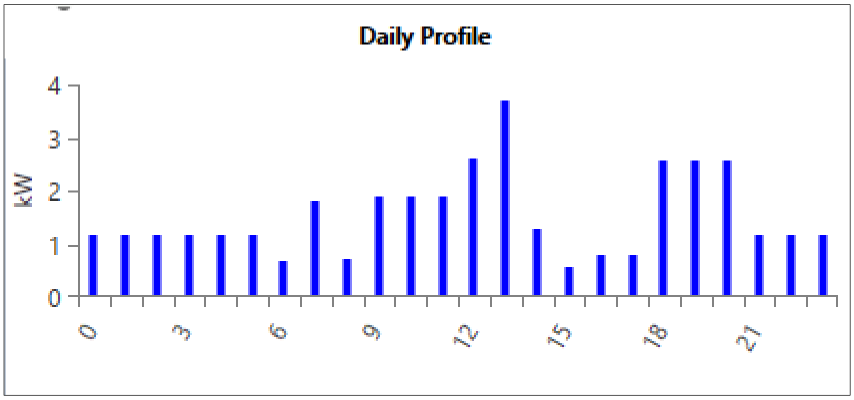


Figure III. 1: Dourbali sub-regional hospital daily load profile

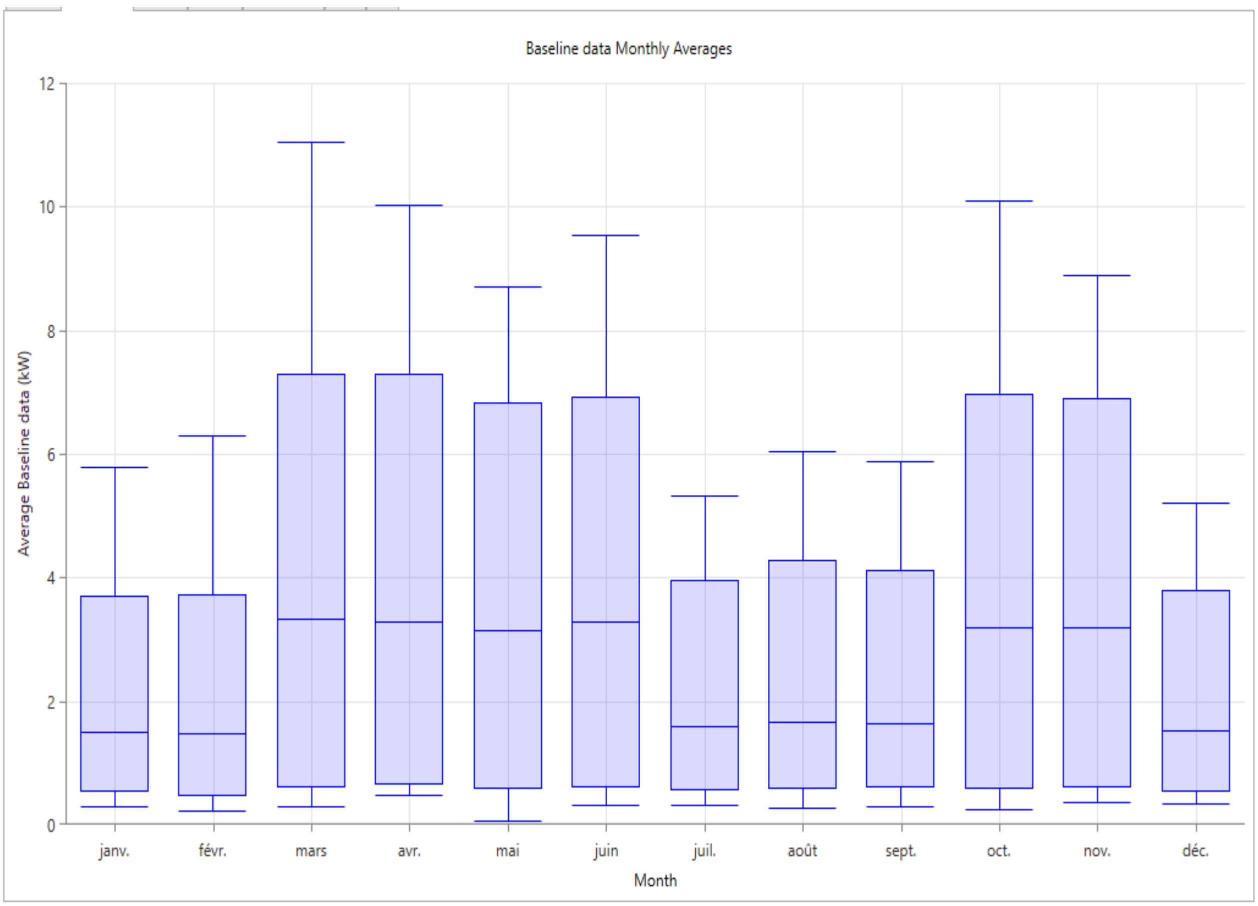


Figure III. 2:: Monthly Load profile

III.5.2 Solar Resource

The monthly daily average global solar radiation on a horizontal surface at the Dourbali region shows by the fig.III.3. The solar radiation data shown in this figure is obtained from the NASA database through the HomerPro interface. The site has, on an annual basis, average daily irradiation of 5.83 kWh/m2 with the lowest average monthly radiation in August (4.92 kWh/m2) and the highest average monthly radiation in November (5.7 kWh/m2**).**

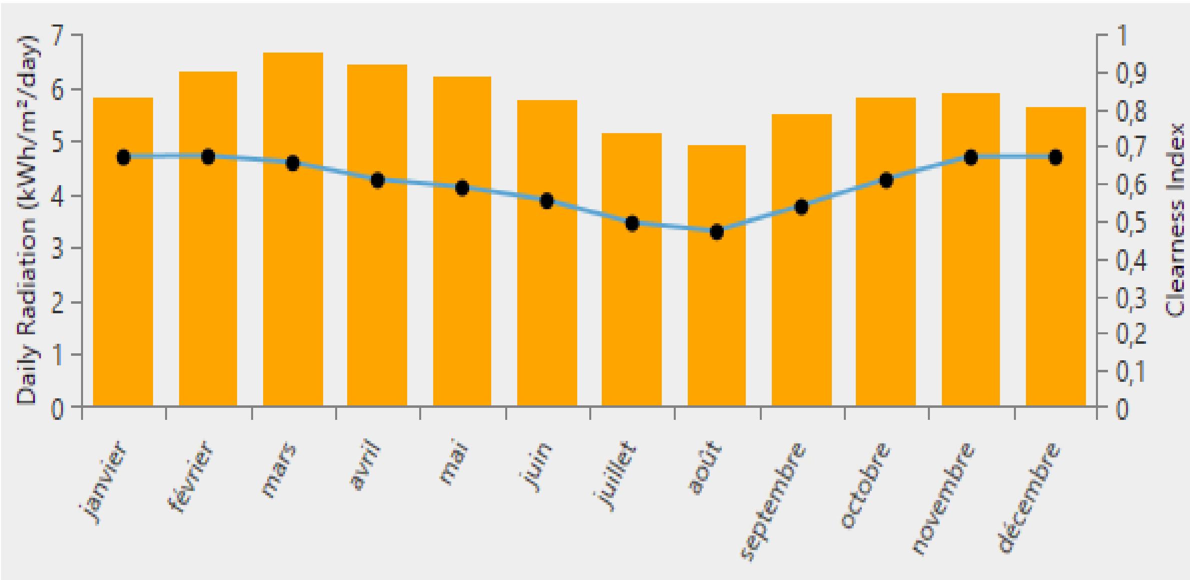


Figure III. 3: average solar global horizontal irradiance

III.5.3 Description of the system used

III.5.1.1 Generator

The diesel generator used in Chad for electricity production mostly bringing from china, so Dourbali sub-regional Hospital use already un diesel generator of 95KVA, the engine cost $1600. The generator consumes 1200 liters per month. No forced on and off was scheduled instead it was left to Homer to optimize it use.

This system chooses an autosize genset from Homer. it adapted automatically with the characteristics and capacity of the Solar PV System. This generator could be started if the storage of electricity in the batteries is insufficient or in case of a major climatic incident that the PV cannot produce.

Table III. 2: Diesel generator characteristics

generator	Autosize Genset (A)
Capital cost	600$/kw
Replacement cost	500$/kw
O&M cost	0.03$/hours
Lifetime	15000 hours

III.5.1.2 Solar PV array

Solar PV array is a network of many modules interconnected to provide terminal voltage, current rating and desired power (Priya , et al., 2017). The principle of solar PV arrays is extremely simple. They consist of a field of photovoltaic solar modules connected in series or in parallel and connected to one or more inverters. Energy is directly transformed into electricity in the panels. The Solar panels are classified in three generations:

The first generation includes monocrystalline and polycrystalline cells which are totally commercial occupy more than 80 % of the market. The second generation are the amorphous PV cells and the third generation are concentrated and organic cells, therefore they are in market development and demonstration stage (Sinton, et al., 2013).

According to the experience done by (S.P. Nehra, et al., 2015) monocrystalline silicon solar cells have paid more intention due to their rapid development of technology and potential applications to fulfill the energy demands of the society. So, this one is the first developed and mostly used solar cells because it has several advantages like low maintenance cost, high reliability, noiseless and eco-friendly. The overall performance of mono-Si solar cell strongly depends on the environmental parameters such as light intensity, tracking angle and cell temperature etc. The efficiency of a solar cell is varied in a range 5%–18% where the lower limit is referred to the amorphous PV cells and the higher limit to the monocrystalline solar cells. Mostly solar PV module lifespan varies around 18 to 25 years.

Table III. 3: Details of PV cell technologies considered

PV:	Generic flat plate PV
Capital cost	3000$/kw
Replacement cost	2000$/kw
O&M cost	1$/year
Efficiency	15%
lifetime	25 years

III.5.1.3 Inverter

The inverter is a key component of the solar PV system. This device is responsible for converting direct current (DC) from the solar panels into alternating current (AC), compatible with the electricity grid and for yield maximization (MPPT's). For sensitivity analysis, inverter efficiency varies between 90% and 95 % where considered the lifespan of 10 to 15 years (Ajao, et al., 2011). therefore, different size was considered but the optimal selected by the software during the optimization.

Table III. 4: Converter input value

converter	Generic system converter
Capital cost	700$/kw
Replacement	700$/kw
O&M cost	70$/kw
Lifetime	15 years
efficiency	95%

III.5.1.4 Storage system

The storage battery is used in the hybrid system to supply energy with its allowable limit (Alayan, 2016). This storage operation aims to reduce the hours of operation of the diesel generator.

For technical design, mixing the PV power stored in the battery with the diesel generation connected to an inter-connected inverter. The range of batteries introduced with HOMER given that the real cost in Chad is 1300 USD with the market of "Amdouria Abousimbil" 15% reduction for more than 100 batteries. The simulation will find the precise size for load demand based on a 48V system.

The selected battery is of type Surrette 4 KS 27P. the latter will affect the life of the system depending on the number of cycles of operation. The battery specifications are given in Table xx, the size of the battery is considered to be compatible with the PV system whose capacity is 1460AH.

Table III. 5: Battery characteristics

Technology	Surrette 4KS25P
Capacity	8.45 kwh
Nominal capacity	1460 Ah
voltage	4
Min. state of charge	40%
Capital cost	1300$
Replacement	1200$
O&M cost	100$/year
Efficiency	80%
lifetime	12

III.5 Comparison of Energy system

The cost analysis of the hybrid PV / diesel system with the grid or back up with the generator was carried out using Homer where the firs was considered as the current system and the second as the basic system. The current and annualized value, the levelized cost of electricity (LCOE), the net present cost (NPC), the return on investment (ROI) and the IRR, the return on investment and the profitability of the discount are the parameters that form the comparison.

III.6.1 Economic Indicators

III.6.1.1 LCOE methods

Levelized costs of electricity (LCOE) are a common metric for comparing power generating technologies (Falko , et al.). It determines the production of one kilowatt hour (kWh) of electricity over the lifetime of a project. There are several ways to calculate LCOE:

- It could be determined by the ratio of the total costs over the duration of the project to the total costs over the life of the project by the amount of electricity produced during the same period, to give an average cost, usually expressed in terms of US cents per kWh.

The costs include capital investment, operating and maintenance (O & M) cost, decommissioning costs, Net Present Cost. Costs and total production per year are discounted at a base date using a discount rate that reflects the cost of capital (Pueyo, et al., 2016).

The following formula use for calculating the LCOE:

$$LCOE = \frac{\sum_{t=0}^{n} \frac{I_t + A_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{M_{t,el}}{(1+i)^t}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (2)$$

Where:

- **I_t**: Investment /capital costs in common currency, his includes engineering, procurement and construction (EPC) costs; infrastructure and connection costs; development costs, including authorization of advisory services or land; assessments of energy resources; insurance and contingencies;
- **A_t**: Annual total costs in year t, they comprise fixed and variable O&M costs;
- **$M_{t, el}$**: Electricity generation in year t in kWh;
- ***i***: Discount rate. The selected discount rate has a considerable influence on the calculated LCOE, with renewable energy technologies more sensitive to high discount rates than fossil fuel plants due to relatively high capital costs and relatively low recurrent costs (Pueyo, et al., 2016).
- ***n***: Operational lifetime in years;
- ***t***: Year of lifetime.

➢ According to (Quansah, et al., 2017) The discounted average cost of energy (LCOE) is calculated as the average cost per kWh of useful electrical energy produced by the system under consideration using the following equation:

$$LCOE = \frac{C_{ann,tot} - C_b * E_{therm}}{E_{prim,Ac} + E_{prim,DC} + E_{def} + E_{grid,sales}}, \quad (3)$$

Where:

- $C_{Ann,}$ tot: is the total annualized cost,
- C_b: is the boiler marginal cost [$/kwh],
- E_{therm}: is the total thermal load served [kwh/yr],
- $E_{prim, DC}$: is the DC primary load served [kwh/yr],
- E_{def}: is the deferrable load served [kwh/yr],
- $E_{grid, sales}$: is the total grid sales [kwh/yr],

III.6.1.2 Net Present Cost (NPC)

Net current cost (NPC) is another important economic indicator and the HOMER model uses it to rank the possible alternatives of the energy system. The NPC is the present value of all the costs it incurs over its lifetime, minus the present value of all the income it earns in its lifetime. it is defined by the equation (Quansah, et al., 2017).

$$NPC = \frac{C_{Ann,tot}}{CRF(i, R_{project})}, \quad (4)$$

Where, CRF is the capital recovery factory, i given interest rate and $R_{project}$ is the project lifetime.

III.6 Simulation systems

The simulation study realizing the different cases to check the effectiveness of a solar PV / Diesel hybrid generation system. All components are using the input data enumerate in the above section by the way in compatibility with the load. The simulated system involves renewable generator which is the PV system including all its components such-as inverter, storage battery and conventional source diesel generator.

HomerPro version 3.9.2 also decides in each time step how to operate the generators and whether to charge or discharge the batteries. It performs these energy balance calculations for each system configuration that you want to consider (HomerProEnergy, 2016). Homer Pro then determines whether a configuration is feasible and can meet the electric demand under the conditions you specify.

And then estimates all necessary costs of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as Net Present Cost, Cost of electricity, capital, replacement, operation and maintenance, fuel, and interest.

III.7 System components and Architecture

The architecture of the proposed solar PV/diesel hybrid system is shown in FigureIII.4 The system comprises a diesel generator connected to the AC bus, the solar PV generator and the battery are connected to the DC bus and the converter which links the two bus bars.

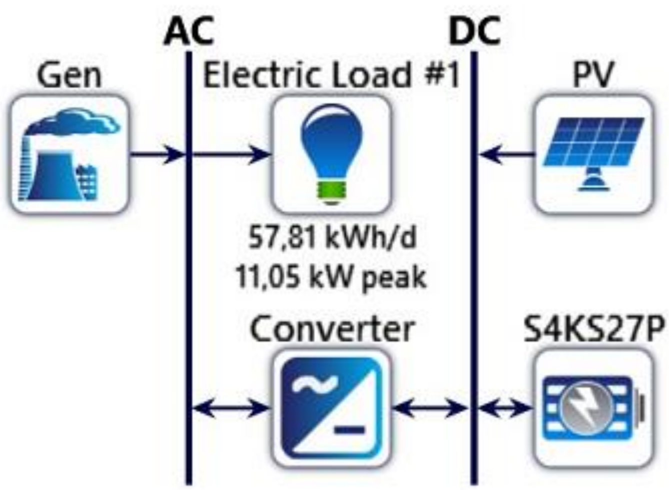


Figure III. 4: schematic of de design system

CHAPTER IV: RESULTS AND DISCUSSION

IV. Introduction to the Results

This section looks at the results from everyday load demand simulated on solar Pv/diesel hybrid system of sub-regional hospital of Dourbali as well as ones obtained from HomerPro analysis and explicitly interpret them. This analysis will cover the technical and economic performance of the system throughout the lifetime of the project, which is approximately 20 to 25 years. The simulation performed with HOMER aims to find the optimized system based on cost and size for existing components.

IV.1 Homer Implementation outcome

IV.1.1 system equipment configuration results

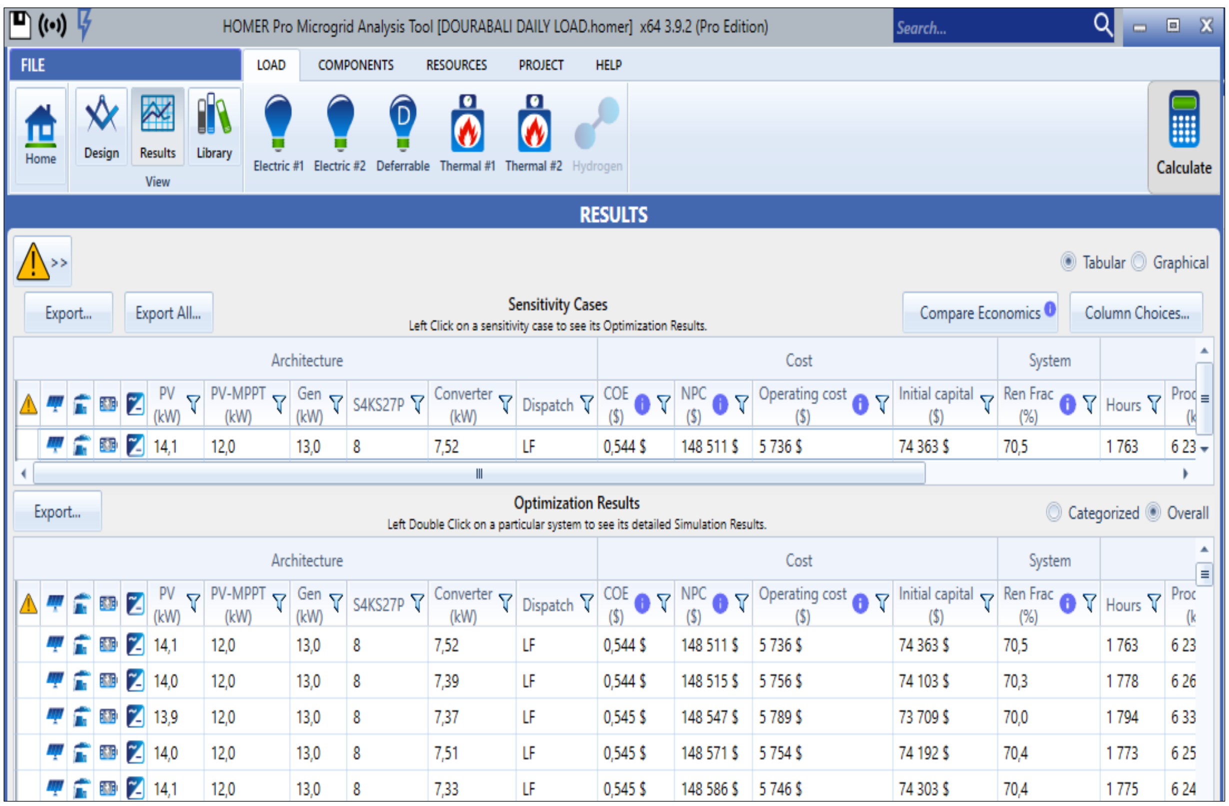


Figure IV. 1: Optimal PV-diesel hybrid power system for the hospital

IV.1.2 Pv generator system performance

The simulation results show that annual PV system output is 20 542 KWh/yr, with an average daily output of 56,3 KWh/d. as well as the value of LCOE which is one of the main parameters of this study is USD $0.201/kwh. See the tableIV.1

Table IV. 1: Generic flat plate PV outcome

Quantity	Value	Units
Maximum Output	10,4	KW
PV Penetration	97,3	%
Hours of Operation	4 330	hrs/yr
Levelized Cost	0,201	$/kWh
Rated Capacity	14,1	KW
Mean Output	2,34	KW
Mean Output	56,3	KWh/d
Capacity Factor	16,7	%
Total Production	20 542	KWh/yr

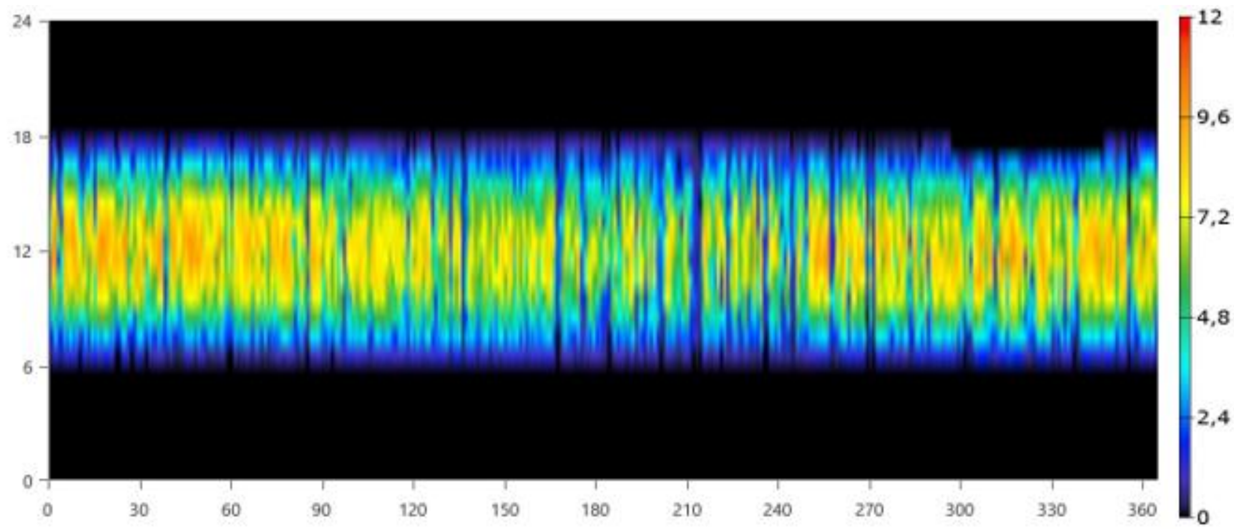


Figure IV. 2:The monthly illustration PV Output (kW)

IV.1.3 Power Converter system

This electronic device "converter" is used to maintain the flow of electricity between AC and DC components. The optimal size of power converter used in this system is 1.82 kW. The process of conversion comes with losses thus less of the produced PV electricity the load as shown in table.

The device operating time is 7 851 hrs/yr.

The system uses two types of converters. One is Sunny boy inverter which converts DC electricity from PV array to AC. The other converter is Sunny Island battery inverter as shown in figure, which is an energy manager of the overall system. It converts DC electricity from Battery into AC electricity with the same voltage and frequency of the bus (Girma*, 2013). It is a bi-directional inverter with the capability of converting AC to DC and inversely.

Table IV. 2: Inverter system output

Quantity	Value	Units
Hours of Operation	7 851	hrs/yr
Energy Out	15 908	KWh/yr
Energy In	16 745	KWh/yr
Losses	837	KWh/yr
Capacity	7,52	KW
Mean Output	1,82	KW
Minimum Output	0	KW
Maximum Output	7,52	KW

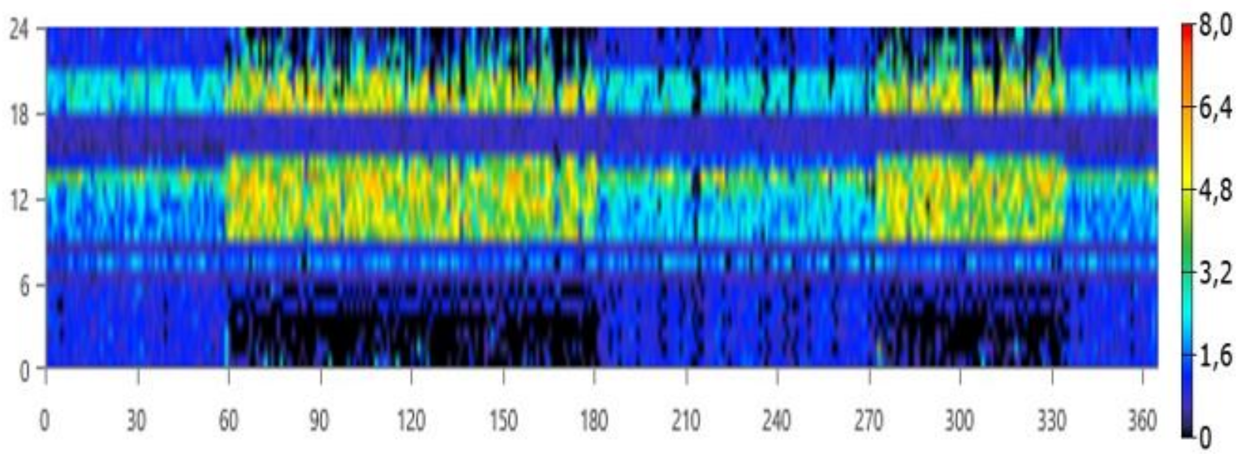


Figure IV. 3: System Converter Inverter Output (kW)

IV.1.4 Storage system performance: Surrette 4 KS 27P

The main difference between a system connected to the network and an off-grid system is the need for a storage system (batteries). that means we need electricity at night while there is no sunlight. So, the results of the simulation show that the annual throughput of 7 965 kWh. With an autonomy of 16.8 hrs and storage depletion is 28.7 KWh/yr. Durant the storage lifetime throughput of 94 475 KWh but it also shows losses 1 778 KWh/yr.

Table IV. 3: Surrette 4 KS 27P Result Data

Quantity	Value	Units
Average Energy Cost	0	$/kWh
Energy In	8 873	KWh/yr
Energy Out	7 124	KWh/yr
Storage Depletion	28,7	KWh/yr
Losses	1 778	KWh/yr
Annual Throughput	7 965	KWh/yr
Autonomy	16,8	hrs
Storage Wear Cost	0,114	$/kWh
Nominal Capacity	67,6	KWh
Usable Nominal Capacity	40,5	KWh
Lifetime Throughput	94 475	KWh

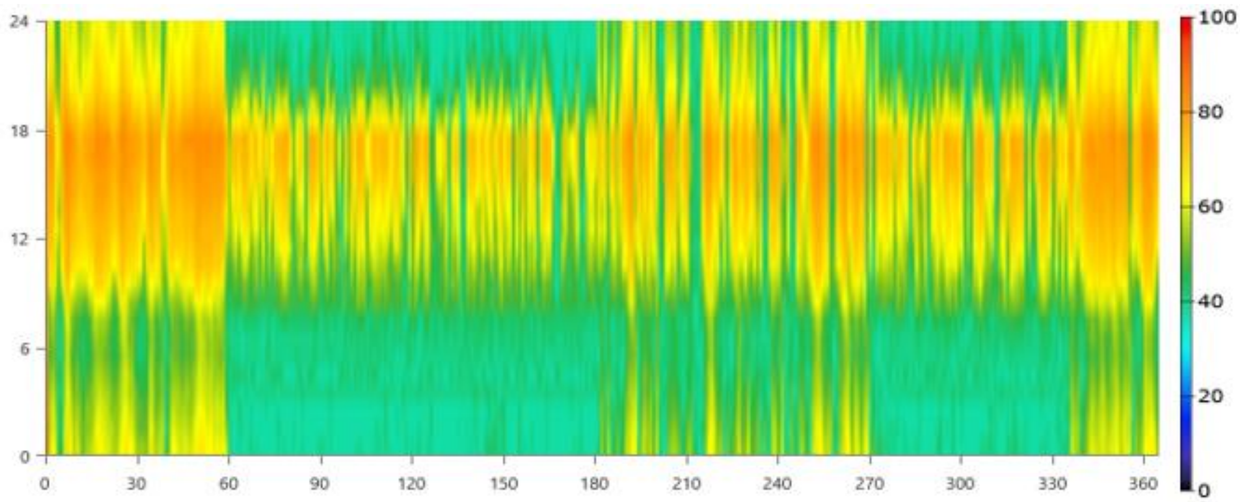


Figure IV. 4: Surrette 4 KS 27P State of Charge (%)

According to the fig IV.4 the state of charge of the battery is higher during cold seasons and low during high consumption months. that means we use a lot of electricity during the months March, April, June, and September, October, November.

IV.1.5 Diesel generator system outcome

Autosize diesel genset is used an optimal configuration. The tableVI.4 shows the different values from the system simulation results. this generator produces an electrical production 6 230 KWh/yr, with main electrical output of 3.53 KW. For this power result, it consumes 2 667 L, and the specific fuel consumption of 0.428 L/KWh, for an operation lifetime of 8.50 years with the hours of operation 1 763 hrs/yr.

Table IV. 4: Autosize genset output

Quantity	Value	Units
Electrical Production	6 230	KWh/yr
Mean Electrical Output	3,53	KW
Minimum Electrical Output	3,25	KW
Maximum Electrical Output	7,99	KW
Fuel Consumption	2 667	L
Specific Fuel Consumption	0,428	L/kWh
Fuel Energy Input	26 247	KWh/yr
Mean Electrical Efficiency	23,7	%
Hours of Operation	1 763	Hrs/yr
Operational Life	8,51	Yr
Capacity Factor	5,47	%
Fixed Generation Cost	1,45	$/hrs
Marginal Generation Cost	0,251	$/kWh

The below figureIV.5 shows that the minimum electricity output is in the cold season which means from December to march and the July to September, with electrical output of 3.25 KW. And maximum is 7.99 KW in hot season which means from March to July and from September to December.

The main advantage of using a bidirectional inverter is, it controls the energy flow to the load and it prolongs the life of battery. As far as enough power is available to power the load from the solar array, the inverter directly supplies the load totally PV without discharging the battery or starting the backup diesel generator (Girma*, 2013). If the load requirement is greater than the capacity of the power system, including the battery and the generator, the inverter sends a signal to the load relay to suppress certain incremental loads.

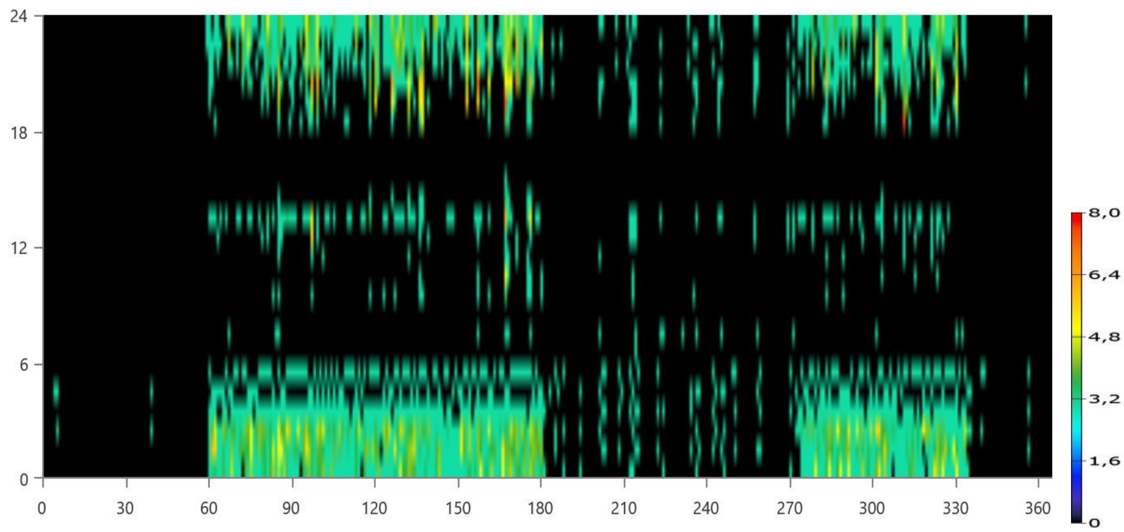


Figure IV. 5: Autosize Genset Output (kW)

IV.2 Economic analysis Results

This section discusses the economic indicators of the project lifetime. Therefore, those indicators include the total net present cost (NPC), levelized cost of electricity (LCOE), energy return on investment (EROI), the project payback time and the cash flow of all component cost.

IV.2.1 Net Present Costs

The net present cost of the system given the table with all details by component and by cost. The total net present cost (NPC) of a system is the present value of all the costs the system incurs over its lifetime, minus the present value of all the revenue it earns over its lifetime. Costs include capital costs, replacement costs, O&M costs, fuel costs (Homer, 2006). The total cost of the system varies by the components. The tableIV.5 shows that the capital cost of whole is 74 363 $ as well as PV has the higher capital cost while the diesel Autosize genset presents 7 800$, so Six (6) times lower than PV.

Table IV. 5: Total net present cost

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Generic flat plate PV	42 152 $	0,00 $	181,64 $	0,00 $	0,00 $	42 333 $
PV Dedicated Converter	9 000 $	2 546 $	0,00 $	0,00 $	-479,12 $	11 067 $
Autosize Genset	7 800 $	6 454 $	8 889 $	34 483 $	-96,02 $	57 530 $
Surrette 4 KS 27P	10 400 $	7 347 $	10 342 $	0,00 $	-2 052 $	26 037 $
System Converter	5 012 $	1 063 $	5 669 $	0,00 $	-200,11 $	11 544 $
System	74 363 $	17 410 $	25 082 $	34 483 $	-2 827 $	148 511 $

The system presents too higher operating and maintenance cost (O&M) 25 083$, in this case the genset, storage batery and the converter have major part of the system O&M cost. The total net present cost of the system is 148 511$.

The same, we observe on the figure below the fuel cost is very high.

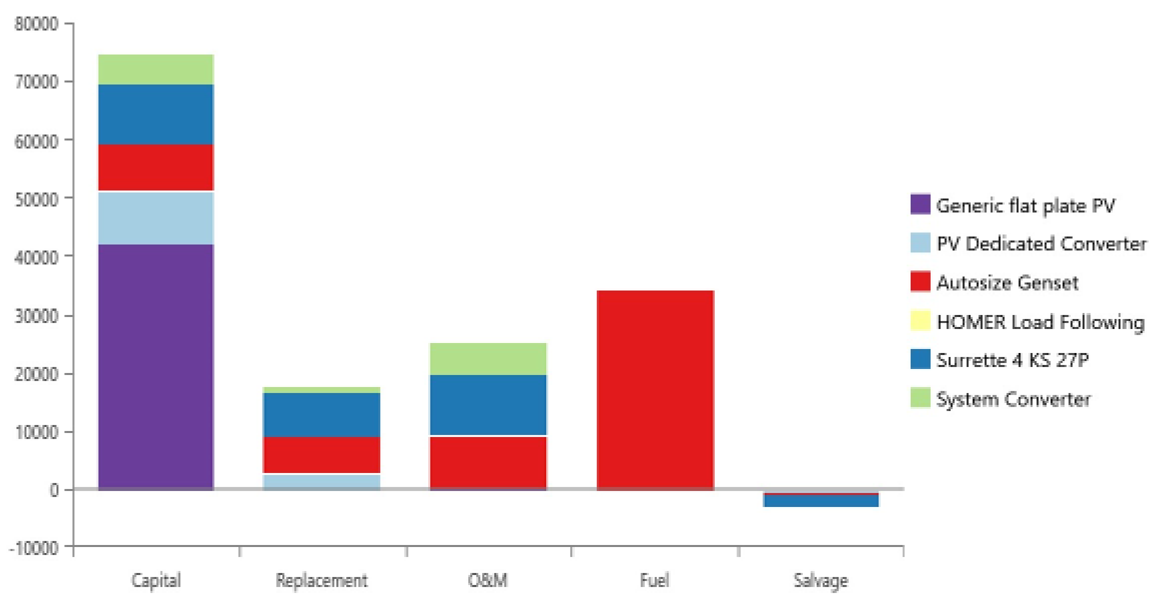


Figure IV. 6: cost summary

IV.2.2 System Cash Flow

The two Cash Flow figures below of the Simulation Results window displays a cash flow chart of the system. First figureVI.7 is the cash flow by cost and second figureIV.8 is the cash flow by component. Therefore, each bar of these graphs represents a total inflow or a total outflow of money of one year. The first bar, for year zero, shows the capital cost of the system, which also appears in the optimization results. A negative value represents an exit, or an expense for fuel, equipment replacement, or operation and maintenance (O & M). A positive value represents an entry, which can be electricity sales revenue or the salvage value of equipment at the end of the life of the project (Rajiv , et al., 2017).

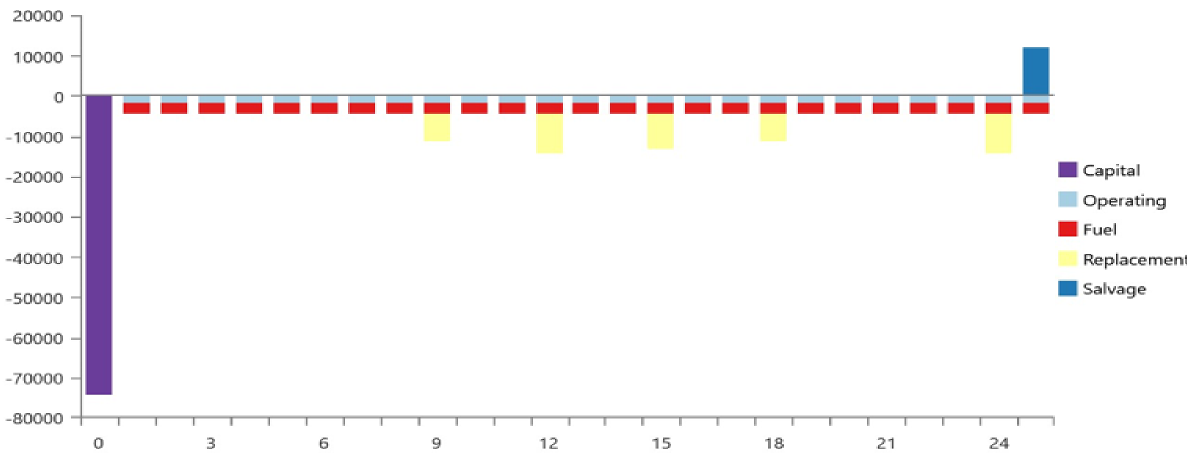


Figure IV. 7: cash flow by cost

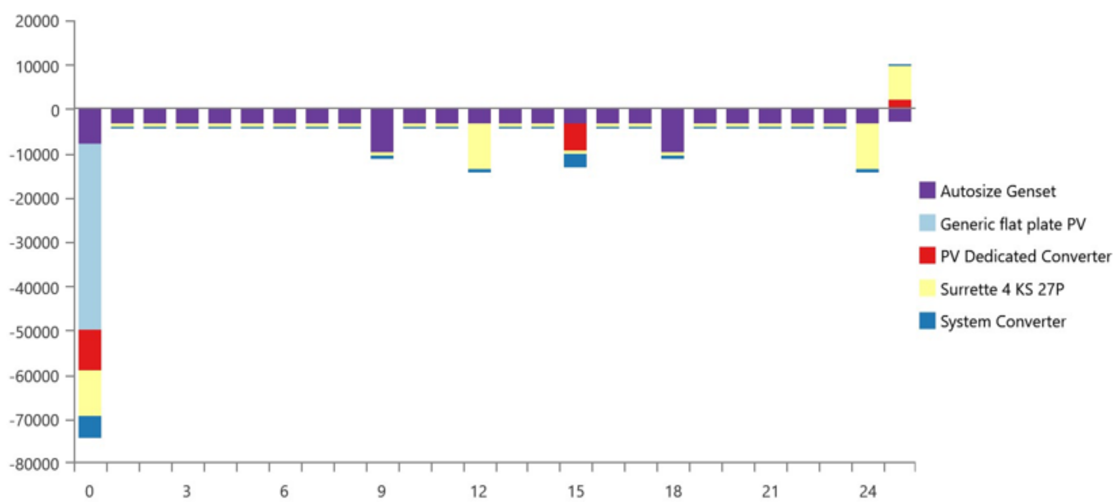


Figure IV. 8: cash flow by component

IV.3 Economic comparison

Architecture										Cost	
					PV (kW)	PV-MPPT (kW)	Gen (kW)	S4KS27P	Converter (kW)	NPC ($)	Initial capital ($)
					8,50	12,0	13,0	9	8,50	163 796 $	59 667 $
					14,1	12,0	13,0	8	7,52	148 511 $	74 363 $

Figure IV. 9: optimal base system and current system, base system in green.

The figureVI.9 above resulting the economic comparison of the hybrid system after simulated et optimized by HomerPro; the green line presents the base system value. So, when we see our PV capacity is 14.1 KW higher than base capacity which is 8.50 KW, while the integrated PV maximum power point tracker (PV-MPPT) system adjust at 12KW. The battery has a slightly different capacity than that of the bass is respectively 8 and 9, As well as the DC-AC converter, the base system presents 8.5 kw and current system 7.52 KW.

According the cost share, when we do a small comparative point of view of our hybrid system, we notice that the base system is too higher than current system in terms of net present cost respectively 163 796$ for the base system and 148 511$ for the current system. But the initial capital cost show as contrary, which means current system is significantly higher than base system respectively 74 363$ and 59 667$.

Table IV. 6: Economic Metrics

Metric	value
Present worth ($)	15 286 $
Annual worth ($/r)	1 432 $/yr
Return on investment (%)	15.7
Intern rate of return (%)	15.2
Simple payback (yr)	6.98
Discounted payback (yr)	7.53

The above tableIV.6, which contains the values of the necessary metrics from the simulation results. The Present worth is the difference between the net present costs (NPC) of the base case system and the current system. So, the present worth is 15 286$.The sign of the present worth indicates whether the current system compares favorably as an investment option with the base case system; A positive value indicates that the current system saves money over the project lifetime compared to the base case system (Homer, 2006). The Annual worth is the present worth multiplied by the capital recovery factor.

comparison of Levelized costs of electricity (LCOE) of solar PV and solar-diesel hybrid generation

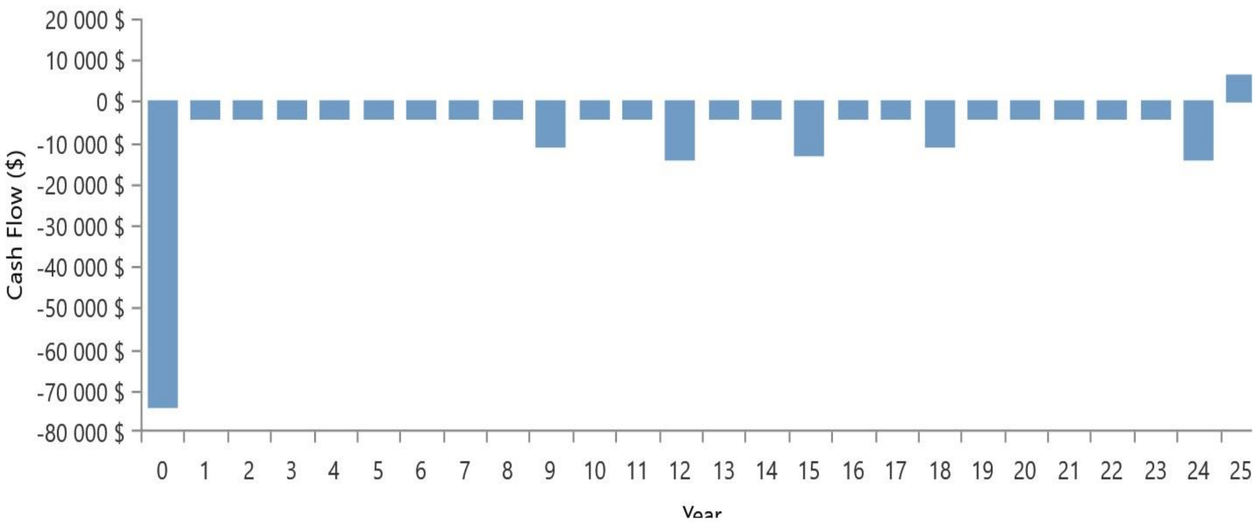


Figure IV. 10: Current Annual Nominal Cash Flow

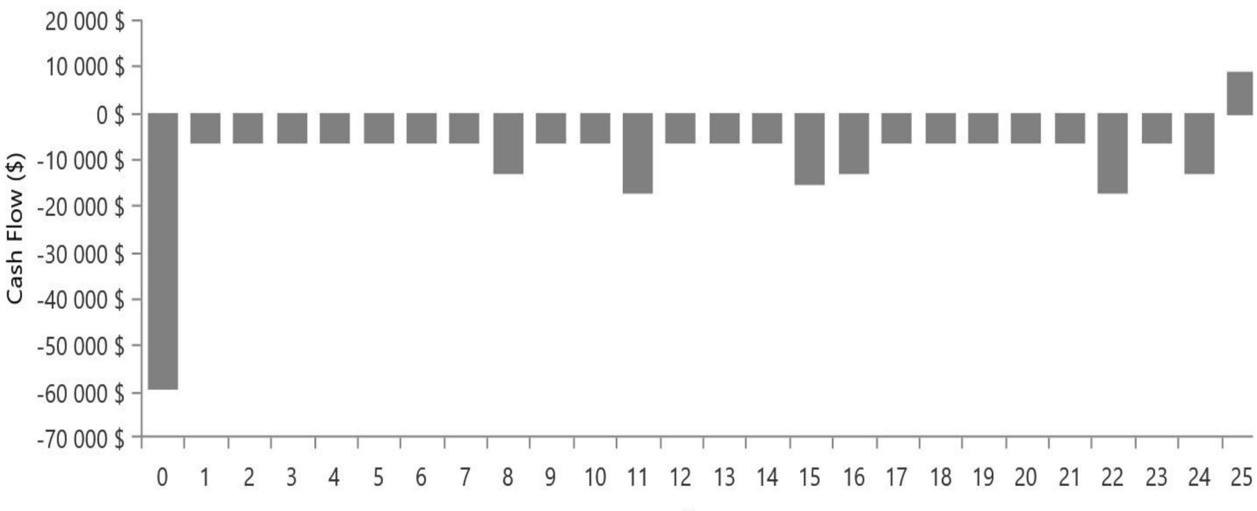


Figure IV. 11: Base Case Annual Nominal Cash Flows

The figureIV.10 and figureIV.11 represent above respectively the current annual nominal cash flow and base case annual nominal cash flow. So, current annual nominal cash flow shows that by the big bleu bar a negative value about -74000$ which means outflow for the investment. While the positive value of inflow is very low is about 10 000$. By the way, the base case presents less outflow than the current -59 000$. These are annual cash flow.

IV.4 Comparison of Levelized costs of electricity (LCOE) of solar PV and solar-diesel hybrid generation

In this section we try to compare the levelized cost (LCOE) of electricity for the solar PV system and solar PV/diesel hybrid system in order to conclude for the decision on the sustainability and more economic. Through the two below tablesIV.7 and tableIV.8, we are deriving the results of the levelized cost of electricity (LCOE) of those different systems which are respectively $0.201/KWh for solar PV and $0.544/KWh for solar PV/diesel hybrid system.

The levelized cost of electricity (LCOE) for the solarPV and SolarPV / hybrid diesel generation system are dependent on solar irradiation of the selected area, the balance of the system including the capital cost of investment and thus the price of fuel, the cost of maintenance, and the harmful noises. The PV systems of the current and future cost structure are competitive with the LCOE of oil generators.

Table IV. 7: PV simulation outcome

Quantity	Value	Units
Minimum Output	0	KW
Maximum Output	10,4	KW
PV Penetration	97,3	%
Hours of Operation	4 330	Hrs/yr
Levelized Cost	0,201	$/kWh

Table IV. 8: System simulation result

Location	Unnamed Road, Dourbali, Chad (11°48,3'N, 15°51,7'E)
Total Net Present Cost	148 510,91 $
System Levelized Cost of Electricity ($/kWh):	0,544 $

IV.5 Emissions Summary

The tableIV.9 below shows the different quantity of GHG emission by annual of the solar-diesel hybrid system from the optimal configuration. This emission includes carbon dioxide (CO2), carbon monoxide (CO), unburned hydrocarbon (UHC), particulate matter (PM) sulfur dioxide (SO2) and finally nitrogen oxide (NOx). The biggest emission of this system is the CO2, which emits 6 982 Kg/yr, followed by the CO and Nitrogen oxides respectively 44 Kg/yr and 41.3 Kg/yr.

Table IV. 9: Comparison of greenhouse gas emission

Quantity	Value (kg/yr)
Carbon Dioxide	6982
Carbon monoxide	44
Unburned hydrocarbon	1.92
Particulate Matter	0.267
Sulfur Dioxide	17.1
Nitrogen oxides	41,3

V. RESULTS DISCUSSION

This section discusses the above results obtained since simulation and optimization of the hybrid solar PV / diesel generation system with HomerPro software by answering the objectives of this thesis.

The study was analyzing the cost of electricity (LCOE, NPC) associated with setting up solar PV/diesel hybrid generation for supply sub-regional hospital of Dourbali, in order to reduce the consumption of diesel fuel, the working hours of diesel generators, as well as the cost from fuel bills. Nowadays the electricity in the sanitary districts is very important. it helps a lot on urgent emergencies such as the operating room, the refrigerator for the medicine stores for the care, the lighting, as well as the other small machines and the cooling system for the hot seasons.

So, daily solar irradiation at the selected site is sufficient to produce electricity from solar photovoltaic system (PV) integrated storage system, according to the data given by NASA database see figureIII.3 the everyday load demand of Dourbali sub-regional hospital that we have determined through our practical survey in the hospital shows too much variation during the day and the year.

The daily consumption profile is very high during the mid-day, between 10am to 2:30 pm, it is the full-time service of the hospital. And the time at which most machines are in using. And the evening from 06 pm to 09:30 pm it means from the sunset until the time to sleep. In addition, this consumption it depends on also the seasonal variation. therefore, the peaks are spring (March, April, May, June) and autumn (September, October, November) and the consumption is lower for the other seasons.

Solar radiation is falling during the rainy season in the months of July and August, when there are completely cloudy days. This is the moment of low profitability for the solar PV system. So that increases the working hours of the diesel engine.

The design of the system began with a detailed study of the data collection that can be used with HOMER.

A fundamental estimate of the data was the load profile for the hospital. The procedure for creating an average consumption profile consisted of estimating the consumption for the hospital on the useful daily energy consumption of the material. The simulation performed with HOMER PRO requires an imported file that contains the annual load profile covering 8760 hours of consumption. At the same time, all components, costs and scope were added to build the PV-diesel hybrid system.

This part was based on facts according to the information on the diesel bills and the electricity consumption by the devices of the sub-regional hospital of the Dourbali. When the director of the Dourbali sub-regional hospital explains that there are sometimes many problems with the diesel generator, among others the shortage of fuel, the winding of the generator if it breaks down. On the other hand, in Chad, whole the electricity on the grid comes from diesel generator, which costs to the government each year more than a billion fcfa approximately $1 818 181 USD by year.

The discussion on system modeling consists of selecting the most available component in Ndjamena market. It is shown by the results of the solar hybrid system pv / diesel generator optimized that the selected components in this simulation have an important performance. The performances of the photovoltaic solar generator with an annual production capacity of 20 542 kWh a year. It includes seasons of low sunlight (rainy seasons) and the system works the 4 330 hours a year. The rated capacity is 14 KW. The solar PV generator levelized cost amounts to $0.201 KWh, this generator admits on average power output of 56.3 KWh/d.

Our system architecture has the components capacity as following: diesel generator Autosize genset 13 KW; solar PV generic flat plat 14.1 KW; with storage system the battery quality Surrette 4 KS 27P of 8 strings and converter system of 7.52 KW. the values of the components (solar panel, controller, regulator, battery, etc.) of the PV generation system used in this study are considered the average market prices of Chad. It was determined by our survey in Ndjamena market, see appendix figure C.

The present system, has excess of electricity 2 980KWh/yr, Unmet Electric Load is 0 KWh/y and shortage 0 KWh/y, as well as the energy production percentage of generic PV flat plate 76,7% and Autosize genset 23.3%.

Cost analysis point of view, the annual cost summery of the system shows by the tableIV.5 and tableIV.6. The annual total cost of the system is $11 488, by which the solar pv capital cost is highest one among the system components is $3,361 and it is annual replacement cost is $0, it is mean that doesn’t need any replacement cost. And the annual Operating & Maintenance cost (O&M) is so low just $14 per year. So, the total annual cost of the solar PV is $3,275. While diesel generator, Autosize genset has annual capital cost of $603.36 per year and the replacement cost and O&M is higher respectively $499.27 and $687.57; the fuel annual cost of the generator is $2 667. So, the total annual cost of Autosize genset is highest one after PV amounts to $4 450. From those value Net present cost of the both generator diesel and PV, it explains that at the starting point, for the investment of the project shows that the PV pay generation system is very expensive compared to the diesel generator but over time the solar PV proves that more economical and cost effective that does not require too much cost for maintenance, replacement, fuel. and no-nonsense noises within the hospital.

Concerning the third goal, it’s analyzing the comparison of the levelized cost of electricity for solar PV and solar PV/diesel hybrid system generation. We have seen the results on the tableIV.7 and tableIV.8 the levelized cost of electricity for solar PV and the hybrid system generation respectively $0.201KWh and $0.544KWh. So, the LCOE for this optimal hybrid system is $0.544/kWh, and it is the lowest cost of electricity compared to diesel-only system and diesel/PV system without battery system is in accordance with the study made by (Prachuab, et al., 2017) in Thailand and (Girma*, 2013) in Ethiopia.

It should be remembered that the Solar PV LCOE has been gradually decreasing since the last decade according to IRENA. This implies the feasibility of our proposal for the hybrid solar PV / diesel system at the sub-regional hospital in Dourbali is much more economical and cost effective than their former diesel generator which overcharges on operating & maintenance costs and fuel cost. Therefore, the economic parameters LCOE ($ 0.544KWh) and NPC ($ 148 511KWh) of this configuration of the hybrid system explains that are satisfied our research question on the first chapter.

The latest reports from IRENA and IEA the costs of solar PV system in the market is gradually decreasing, as well as components such as the converter, the battery, MPPT are falling price. Thus, industries develop advanced technologies every day with a very good efficiency of each component. Given the economically reliable and cost-effective results of this studies on the costs of hybrid solar PV and Solar PV / diesel system the access of electricity on available. And so, the configuration of the hybrid system is very friendly with the environment because the emission of GHG is reduced.

Chapter V: Conclusion and Recommendations

This study is analyzed the cost of electricity (LCOE, NPC) associated with setting up solar PV/diesel hybrid generation with the integration of the storage system by Homer pro. Optimized results of the hybrid system (solar PV/diesel) have been obtained using Homer software.

Economically, the solar PV presented a levelized cost of US $0.201/KWh while the marginal cost of diesel generator is $0.251/KWh. The Net Present cost of Solar PV and diesel generator is respectively US $42 333 and US $57 530 for each. With regards the total annual cost, the diesel generator has a higher cost (US $4 450) than the solar PV (US $3275). Additionally, results have shown that the capital cost solar PV was up to US $57 563, including the cost of all components (converter, battery etc.) while the diesel generator has only US $7 800. Therefore, the Solar PV system capital cost is seven (7) times higher than diesel. But, the O&M cost of solar PV array was lower than diesel generator which are respectively US $ 181.64 and US $8 889.

The statistic results are 97% for PV penetration and the capacity factor is 16.7%, with a total daily power output of 56.3 KWh/d. The diesel generator has 23.7% of mean electrical efficiency and 5.47% of capacity factor.

For the solar PV/diesel hybrid generation system, the results have shown that the value of LCOE and NPC are respectively US $ 0.544/KWh and US $ 148511/KWh. The system generates the total of 26 771 KWh/yr. The advantages of this configuration, is that most of power is generated from renewable energy source as shown here, where the solar PV generates up to 76,7 % while for diesel generator it is 23.3 % of the total power.

Based on previous technical and economic results, it can be concluded that the cost of the hybrid system is good and could be achieved throughout the sub-region, as well as in all rural and sub-urban areas that are far from the national electrical grid. In terms of fuel consumption, it is only about 7.31 L/d for the hybrid system (Solar PV/diesel) in comparison to the current diesel generator used in Dourbali sub-regional hospital with a consumption of 53.3 L/d. However, the fuel consumption and hours of operation of the generators decreased when the solar energy increase. For better energy saving and environmental concerns, the optimized hybrid system proves a better system than the solar PV and generator site alone. Thus, there would be diversification and a good energy mix in the rurales and sub-urban area when public institution (hospital, school, mosque, offices) or private (small company, market, etc.). As a recommendation for future work, it would be a further study on the same hybrid configuration but to cover the whole town by a mini-grid interconnected between public institutions (school, mosque, offices, FM radio, etc.).

Recommendations:

Through this study, the government could put in place a reliable policy options that will facilitate the exploitation of renewable resources in order to improve access to electricity for vulnerable populations in rural areas. Trained the experts to analyze the renewable energy project.

Using several renewables sources for the simulation such as wind, biomass to make more efficiency the sustainability of electrical generation.

By this way, invite the international institutions such as UNDP, UNFPA, the donors and NGO's to contribute on the rural development.

In addition, installers and vendors should also consider what type of hybrid system will be best for a particular location before deploying the system to the site.

It is also recommending a pilot survey to determine the rate of access to solar PV electricity to the government agencies such as Ader-Chad and SNE. By the same opportunity raise awareness of the use of solar PV for Solar Home System (SHS) or off-grid using in peri-urban and rural areas. It is solicited a market study on renewable energy materials and their sources of provenance, which policy the Chad government uses for customs barriers.

Bibliography

AbdelHady Rameen Modeling and simulation of a micro grid-connected solar PV system [Journal]. - Cairo : ELsiver, 2017. - 31 : Vols. 1-10.

ACF . Analyse de biomasse energie ressource au Tchad [Report]. - 2016.

Ader-Tchad solar system components [Report]. - 2014.

Ajao K.R., O.A.Oladosu and O.T. Popoola USING HOMER POWER OPTIMIZATION SOFTWARE FOR COST BENEFIT ANALYSIS OF HYBRID-SOLAR POWER GENERATION RELATIVE TO UTILITY COST IN NIGERIA [Journal]. - Ilorin : [s.n.], 2011. - 1 : Vol. 7(April).

Alayan Sophia Design of a PV-Diesel Hybrid System with Unreliable Grid Connection in Lebanon // Thesis Solar Energy Engineering . - [s.l.] : ESES, 2016.

Baghdadi Ilham [et al.] performance investigation solar PV connect to the grid [Journal]. - Tirgu-Mures : ELSEVIER, 2018. - 22 : Vols. 667–674.

Changjie Yin [et al.] Energy management of DC microgrid based on photovoltaic combined with diesel generator and supercapacitor [Journal]. - compiegne : Elsevier, 2017. - 132 : Vols. 14-27.

Chiemeka Onyeka Okoyea and Blessing Chioma Oranekwu-Okoyeb Economic feasibility of solar PV system for rural electrification in SubSahara Africa [Journal]. - Nigeria : ELSEVIER, 2016. - 1364-0321.

EU-Chad DECISION of on the financing of a Global Plan for humanitarian operations [Report]. - 2008.

F.S. Javadi, B. Rismanchi, al Global policy of rural electrification [Journal] // Renewable and Sustainable Energy Reviews . - malaya : Elsevier, 2013. - 19 : Vols. 402–416. - pp. 402-416.

Falko Ueckerdt [et al.] System LCOE: What are the costs of variable renewables? [Journal]. - Postdam : [s.n.].

Girma* Zelalem Technical and Economic Assessment of solar [Journal]. - ADIS ABABA : INTERNATIONAL JOURNAL of RENEWABLE ENERGY RESEARCH , 2013. - 3 : Vol. 3.

Gunther Benschc [et al.] Are promotion programs needed to establish off-grid solar energy markets? Evidence from rural Burkina Faso [Journal]. - ouaga dougou : ELSEVIER, 2017.

Hamilton J.M. [et al.] Utilization and Optimization of Diesel generation for maximum renewable power integration [Journal]. - Islant : spienter, 2017. - 364 : Vol. 1.

Homer [Online] // homer custom resources. - 2006. - JULY 19, 2018. - https://www.homerenergy.com/products/pro/docs/3.11/net_present_cost.html.

HomerProEnergy HOMER® Pro Version 3.7 user manuel [Book]. - USA : Boulder Co, 2016.

INSEED-TCHAD deuxieme resencement general de la population et de l'habitats [Report]. - Ndjamena : INSEED, 2012.

IRANA Solar PV in africa cost and market [Report]. - Abou dabi : IRENA, 2016.

IRENA Africa, remape renewable energy 2030 [Report]. - DOUBAI : IRENA, 2015.

IRENA RENEWABLE ENERGY TECHNOLOGIES: COST ANALYSIS SERIES [Report]. - ABU DABI : IRENA, 2012.

IRENA Solar PV in Africa: cost and market [Report]. - [s.l.] : IRENA, 2016.

JONATHAN HOMER Help Manual [Book]. - 2015.

kabir Ehsanu Solar energy: Potential and future prospects [Journal] // Renewable and Sustainable Energy Reviews. - 2018. - pp. 894-900.

Kabir Ehsanul and PAWAN KUMAR Solar energy: future prospects [Journal] // Elsevier. - 2018. - pp. 894-900.

Kittner Noah, Shabbir H. Gheewala and Daniel M. Kammen Energy return on investment (EROI) of mini-hydro and solar PV [Journal]. - [s.l.] : Elsevier, 2016. - 99 : Vol. 410e419.

Lai Chun Sing and Malcolm D. McCulloch Levelized cost of electricity for solar photovoltaic and electrical energy [Journal]. - london : ELsevier, 2017. - 190 : Vols. 191–203.

Laith M Halabi [et al.] Performance analysis of hybrid PV/diesel/battery system using HOMER:A case study Sabah, Malaysia [Journal] // Energy Conversion and Management. - Sabah : Elsevier, 2017. - 44 : Vol. 1. - pp. 322–339.

Minister energy laws and regulation [Report]. - 2008.

Muyiwa S. Adaramola Viability of grid-connected solar PV energy system in Jos, Nigeria [Journal]. - JOS : Elsevier, 2014. - 61 : Vols. 64–69.

NREL [Online] // htttp://www.homerenergy.com/. - juley 1, 2017.

Prachuab Peerapong and Bundit Limmeechokchai Optimal electricity development by increasing solar resources in diesel-based micro grid of island society in Thailand [Journal]. - Tailand : ELSEVIER, 2017. - 1 : Vol. 3.

Priya Ranjan Satpathy, Renu Sharma and Sasmita Jena A Shade Dispersion Interconnection Scheme for Partially Shaded Modules in a Solar PV Array Network [Journal]. - Bhubaneswar, India : Elsevier, 2017. - 350-365 : Vol. 139.

Pueyo Ana, Simon Bawakyillenuo and Helen Osiolo Cost and Returns of Renewable Energy in Sub-Saharan Africa: A Comparison of Kenya and Ghana [Report]. - UK : DS Pro-Poor Electricity Provision, 2016.

Quansah David A. [et al.] TECHNO-ECONOMICS OF SOLAR PV–DIESEL HYBRID POWER SYSTEMS FOR OFF-GRID OUTDOOR BASE TRANSCEIVER STATIONS IN GHANA [Journal] // International Journal of Energy for a Clean Environment. - Acra : Begell House, 2017. - 1 : Vol. 18. - pp. 61–78.

Rajiv Ranjan Kumar, Abhishek Kumar r Gupta and Ashish Ranjan Kumar Design and Simulate the Solar-Wind-Diesel Stand-Alone Systems for an Institutional Area [Journal] // International Journal of Computer Applications. - jaipur, India : [s.n.], 2017. - 12 : Vol. 165. - pp. 0975 – 8887.

S.P. Nehra [et al.] Impact of temperature on performance of series and parallel connected mono-crystalline silicon solar cells [Journal]. - [s.l.] : Elsevier, 2015. - 175-180 : Vol. 1.

Sinton Christopher W., Butler and winnet R Guide to Solar-Powered Water Pumping Systems in NYS - NYSERDA [Report]. - NEW YORK : NYSERDA, 2013.

SNE-TCHAD les nouveaux tarifs d'electricité au TCHAD [Report]. - NDjamena : [s.n.], 2012.

Veldhuis A.J. and A.H.M.E. Reinders Reviewing the potential and cost-effectiveness of off-grid PV systems [Journal]. - indolnosia : Elsevier , 2015. - 52 : Vols. 757–769.

APPENDICES

A. Solar irradiation

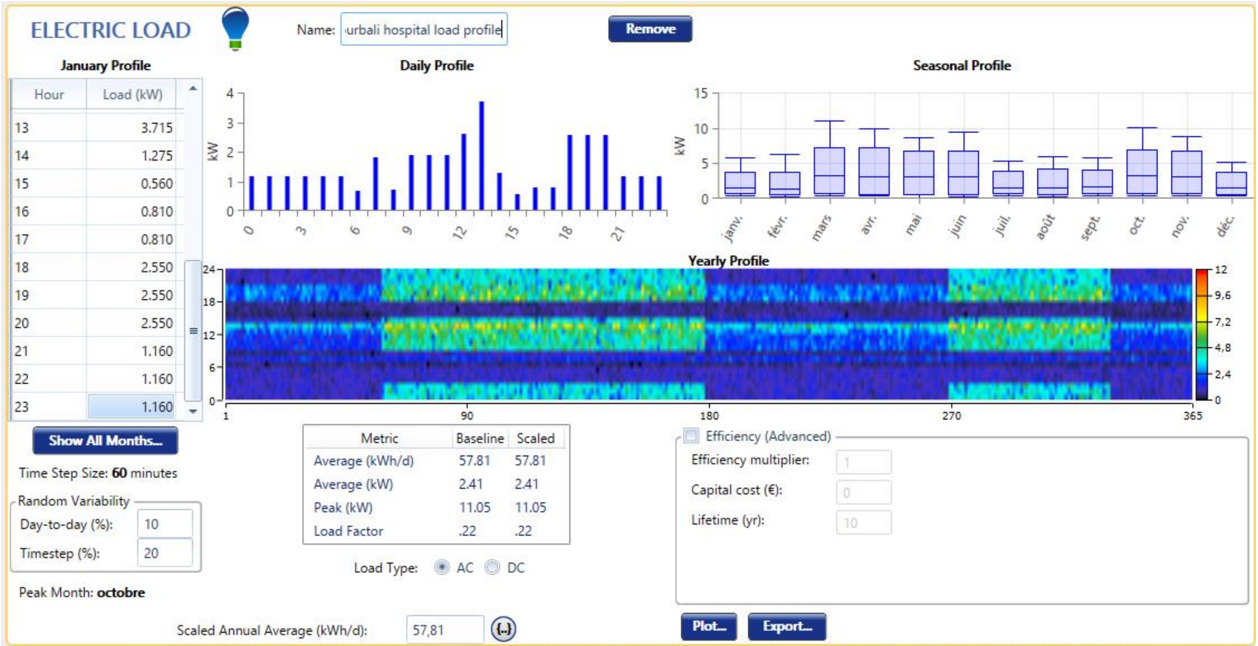
January	0.669	5.790
February	0.671	6.300
March	0.654	6.630
April	0.608	6.410
May	0.588	6.190
Jun	0.553	5.760
Juley	0.493	5.140
August	0.470	4.920
September	0.537	5.490
October	0.608	5.820
November	0.669	5.880
December	0.669	5.610

B. Daily load of all months

Hour	janvier	février	mars	avril	mai	juin	juillet	août	septembre	octobre	novembre	décembre
0	1.160	1.160	3.860	3.860	3.860	3.860	1.160	1.160	1.160	3.860	3.860	1.160
1	1.160	1.160	3.860	3.860	3.860	3.860	1.160	1.160	1.160	3.860	3.860	1.160
2	1.160	1.160	3.860	3.860	3.860	3.860	1.160	1.160	1.160	3.860	3.860	1.160
3	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160
4	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160
5	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160	1.160
6	0.685	0.685	0.685	0.685	0.685	0.685	0.685	0.685	0.685	0.685	0.685	0.685
7	1.810	1.810	1.810	1.810	1.810	1.810	1.810	1.810	1.810	1.810	1.810	1.810
8	0.710	0.710	1.010	1.010	1.010	1.010	0.710	0.710	0.710	1.010	1.010	0.710
9	1.900	1.900	4.600	4.600	4.600	4.600	2.200	2.200	2.200	4.600	4.600	1.900
10	1.900	1.900	4.600	4.600	4.600	4.600	2.200	2.200	2.200	4.600	4.600	1.900
11	1.900	1.900	4.600	4.600	4.600	4.600	2.200	2.200	2.200	4.600	4.600	1.900
12	2.615	2.615	5.315	5.315	5.315	5.315	2.975	2.975	2.975	5.375	5.375	2.615
13	3.715	3.715	6.415	6.415	6.415	6.415	4.000	4.000	4.000	6.415	6.415	3.715
14	1.275	1.275	3.975	3.975	3.975	3.975	1.575	1.575	1.575	3.975	3.975	1.275
15	0.560	0.560	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.860	0.560
16	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810
17	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810	0.810
18	2.550	2.550	5.250	5.250	5.250	5.250	2.550	2.550	2.550	5.250	5.250	2.550
19	2.550	2.550	5.250	5.250	5.250	5.250	2.550	2.550	2.550	5.250	5.250	2.550
20	2.550	2.550	5.000	5.000	5.000	5.000	2.550	2.550	2.550	5.000	5.000	2.550
21	1.160	1.160	3.860	3.860	3.860	3.860	1.160	1.160	1.160	3.860	3.860	1.160
22	1.160	1.160	3.860	3.860	3.860	3.860	1.160	1.160	1.160	3.860	3.860	1.160
23	1.160	1.160	3.860	3.860	3.860	3.860	1.160	1.160	1.160	3.860	3.860	1.160

Source: Homer

C. Hospital load all parameters



D. Summary of simulation results

Simulation Results

System Architecture:

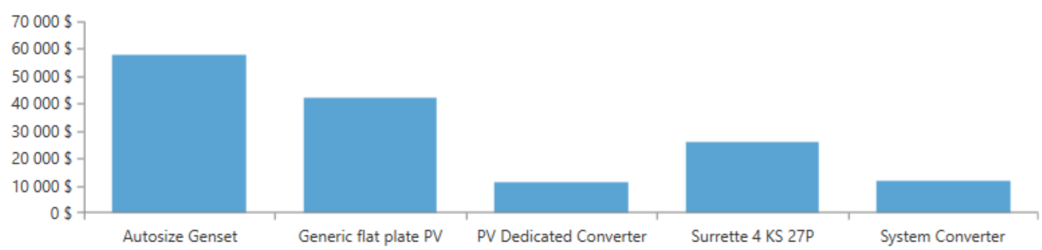
Generic flat plate PV (14,1 kW/12,0 kW) System Converter (7,52 kW)
Autosize Genset (13,0 kW) HOMER Load Following
Surrette 4 KS 27P (8,00 strings)

Total NPC:	148 510,90 $
Levelized COE:	0,5444 $
Operating Cost:	5 735,63 $

System Converter Emissions
Cost Summary Cash Flow Compare Economics Electrical Fuel Summary Autosize Genset Renewable Penetration Surrette 4 KS 27P Generic flat plate PV

Cost Type
Net Present
Annualized

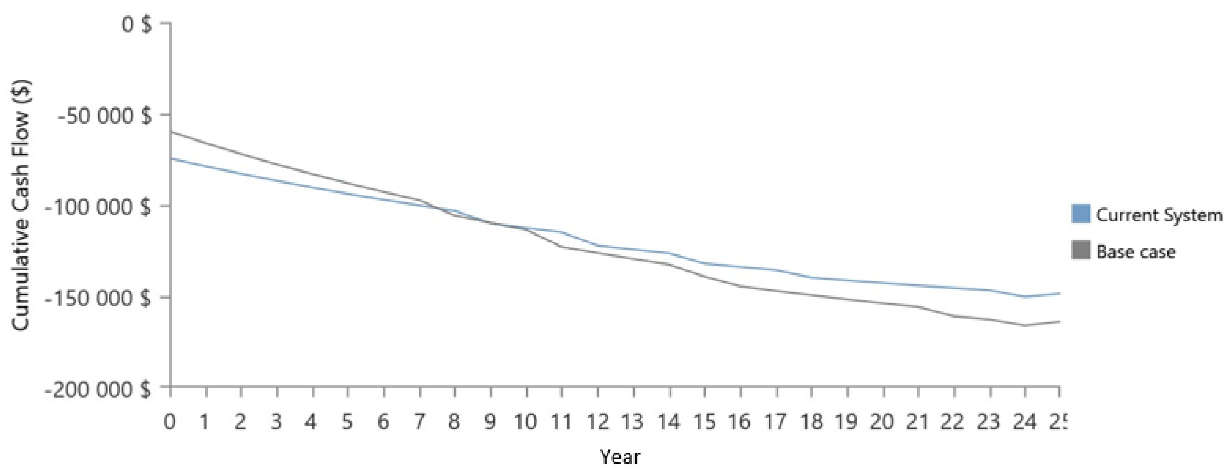
Categorize
By Component
By Cost Type



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Autosize Genset	7 800,00 $	6 454,33 $	8 888,57 $	34 483,11 $	-96,02 $	57 529,98 $
Generic flat plate PV	42 151,51 $	0,00 $	181,64 $	0,00 $	0,00 $	42 333,15 $
PV Dedicated Converter	9 000,00 $	2 545,64 $	0,00 $	0,00 $	-479,12 $	11 066,53 $
Surrette 4 KS 27P	10 400,00 $	7 347,11 $	10 342,01 $	0,00 $	-2 052,25 $	26 036,88 $
System Converter	5 011,95 $	1 063,22 $	5 669,31 $	0,00 $	-200,11 $	11 544,38 $
System	74 363,46 $	17 410,30 $	25 081,53 $	34 483,11 $	-2 827,50 $	148 510,91 $

Renewable Summary

Capacity-based metrics	Value	Unit
Nominal renewable capacity divided by total nominal capacity	51,9	%
Usable renewable capacity divided by total capacity	46,4	%
Energy-based metrics	**Value**	**Unit**
Total renewable production divided by load	97,3	%
Total renewable production divided by generation	76,7	%
One minus total nonrenewable production divided by load	100	%
Peak values	**Value**	**Unit**
Renewable output divided by load (HOMER standard)	2 431	%
Renewable output divided by total generation	100	%
One minus nonrenewable output divided by total load	100	%



Cumulative Discounted Cash Flows

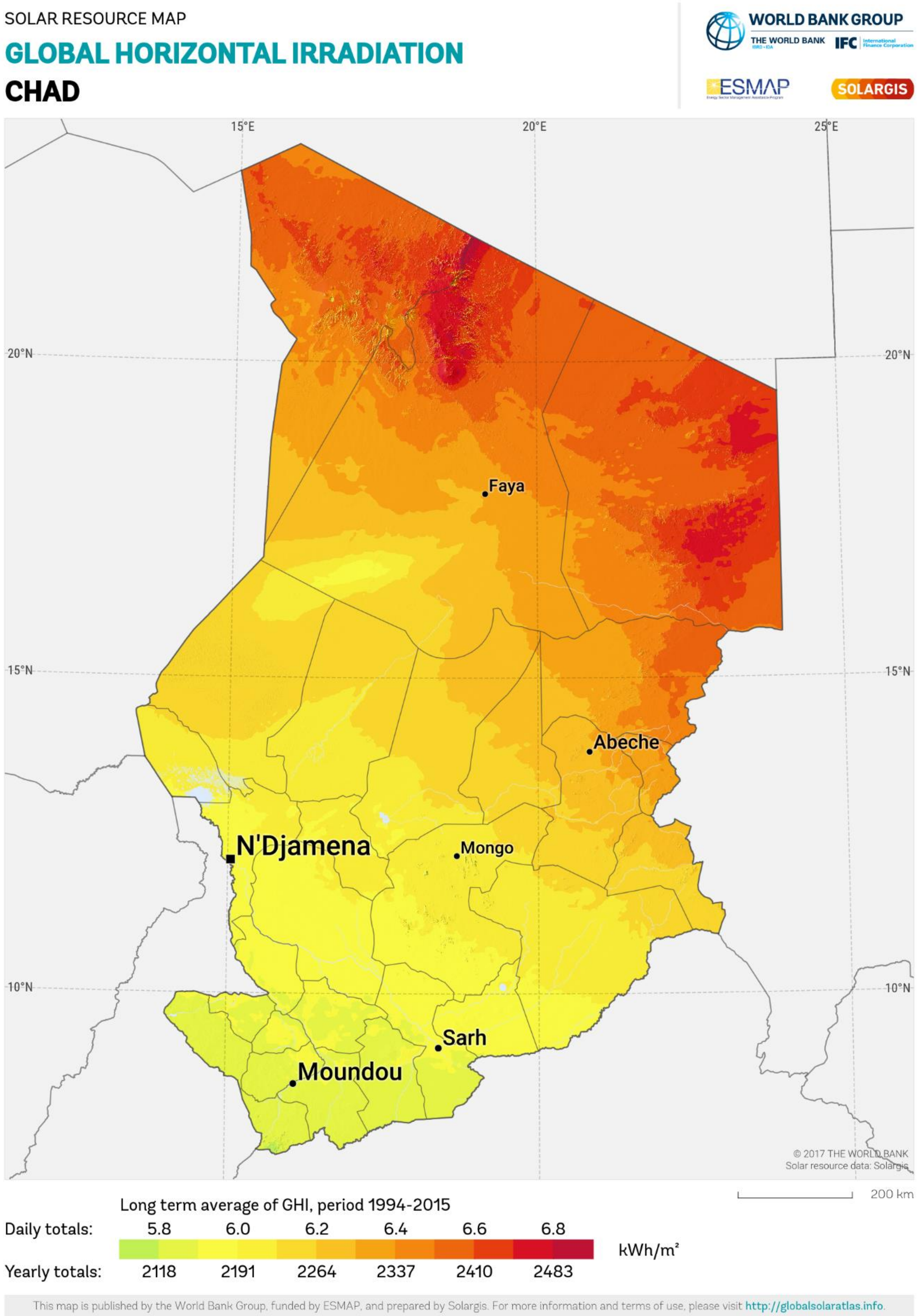
E. Prix of solar PV system equipment in Chad

N°	Type d'Equipement	Quantité	Prix unitaire	Observation
1	Panneaux Solaire de 20 W	1	25000	
2	Panneaux Solaire de 50 W	1	75000	
3	Panneaux Solaire de 100 W	1	125000	
4	Panneaux Solaire de 190 W	1	300000	
5	Panneaux Solaire de 200 W	1	350 000	
6	Panneaux Solaire de 205 W	1	375000	
7	Panneaux Solaire de 250 W	1	400000	
8	Panneaux Solaire de 300 W	1	500000	
9	Panneaux Solaire de 305 W	1	550000	
10	Batterie de 20Ah	1	35000	
11	Batterie de 40 Ah	1	70000	
12	Batterie de 50 Ah	1	85000	
13	Batterie de 60Ah	1	100000	
14	Batterie de 100 Ah	1	125000	
15	Batterie de 120 Ah	1	150000	
16	Batterie de 200 Ah	1	225000	
17	Convertisseur de 300W	1	35000	
18	Convertisseur de 500 W	1	50 000	
19	Convertisseur de 800 W	1	85000	
20	Convertisseur de 100W 1000W	1	105 000	
21	Convertisseur de 2000W	1	225000	
22	Convertisseur de 3000W	1	400000	
23	Régulateur de 10	1	30000	
24	Régulateur de 20	1	75000	
25	Régulateur de 30	1	100000	
26	Régulateur de 40	1	150000	
27	Régulateur de 50	1	250000	
28	Régulateur de 100	1	500 000	
29	Lampe de 3 W	1	3500	
30	Lampe de 5 W	1	4500	
31	Lampe de7 W	1	6000	
32	Lampe de 9W	1	7000	
33	Lampe de 12W	1	7500	
34	Lampe de 16 W	1	8000	
35	Lampe de 20 W	1	9000	
36	Lampe de 22W	1	10500	

Ets WORLD Business Tchad

Figure E: pv equipment,

F. Solar radiation map of Chad for PV power generation


SOLAR RESOURCE MAP
GLOBAL HORIZONTAL IRRADIATION
CHAD
WORLD BANK GROUP
THE WORLD BANK
IFC
ESMAP
SOLARGIS
15°E
20°E
25°E
20°N
15°N
10°N
Faya
Abeche
N'Djamena
Mongo
Sarh
Moundou
© 2017 THE WORLD BANK
Solar resource data: Solargis
200 km
Long term average of GHI, period 1994-2015
Daily totals: 5.8 6.0 6.2 6.4 6.6 6.8
kWh/m²
Yearly totals: 2118 2191 2264 2337 2410 2483
This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit http://globalsolaratlas.info.

Satellite localization of Dourbali Hospital

G. Questionnaire model

Agence de développement
Des énergies renouvelables

PAUWES Master thesis data collection

Interview guide to the hospital staffs in Dourbali

The main reason for these questionnaires was to determine the electricity load demand of the health center of Dourbali.

Please kindly fill the following. Two minutes of your time will be grateful for us.

1) What is source of electricity supply the hospital?
   - ➢ Solar PV ☐
   - ➢ Diesel ☐
   - ➢ All above ☐
2) What are electricity difficulties you face?
3) What are the main appliances need electricity in the hospital?

Area	appliances	Qty	Power (W)	Total power of items	Hours/ day and night		Watt hour/day, night		
					day	night	day	night	Total kwh

everyday load demand of the regional hospital.

Appendix

Research budget plan			
Items	**Clarification**	**Cost/unit**	**Total cost ($)**
Fly ticket	For research internship and data collection, the second ticket for the penalties because I missed the first flight, caused by the incident due to weather conditions to Alger the day of the trip and arrived late at the airport.	1st =$1200 2nd=$480	$1680
Training for data analysis	This training was solar PV cost & market data analyzing	$265	$265
Software	Homer pro software standart version license was paid for three months, it should have been a student version but the procedure to have affiliation is very long and time wasted for my thesis. Firstly, I paid for two months at end my supervisor request restart the simulation, so I should have added another one month for completed my work	$185/month	$555
Internal transport	I have traveled 4 times to Dourbali for collecting data and determine the hospital daily load.	$36.4/Trip	$146
Internet navigation for research	In Chad the internet is most expensive in Africa, it $25/GB. But I got subscribe in a cyber café (internet café) for three months. So, it cost for me $132 per month	$131	$193
Total			**= $ 3000**

Receipts:

RMD-EVOLUTION-SERVICE
Commerce Général
Vente des consommables Informatiques, Maintenance ; Internet ; Photocopié et Impression, Saisie et Scan ; Abonnement des Chaines; Montage des Cartes & Badge ; Films & Affiche.
N° Cpt: 60572720101276708846 Eco
Nif : BP: Tél : (+235) 99150925/66305321

le 05 Juin 2018

FACTURE N° 07

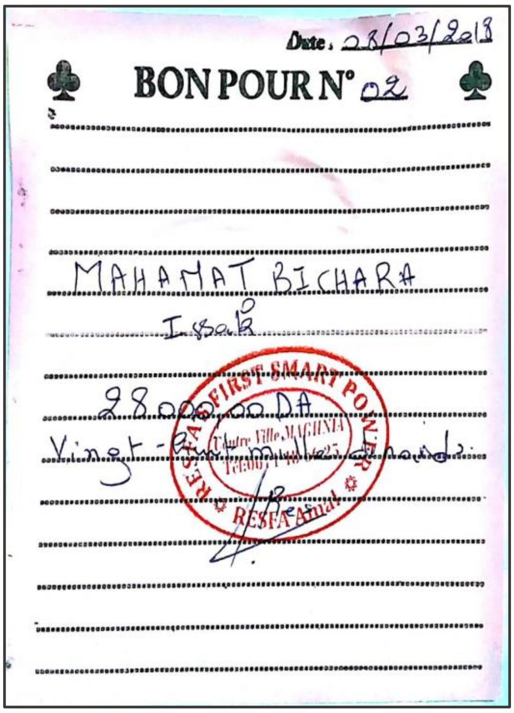
Mr : Mahamat Bichara Issak
Pour les fournitures suivantes.

N°	Désignation	Qte	P. Unitaire	P. Total
01 02 03 04	Axes internet illimité de 3heurs par jours 4 fois par semaines qui font 12h 12 heurs par semaine pendant 1 mois 48 heurs pour un mois et pendants trois (3) mois qui font 144heurs.	3h/jrs 1mois 48hx3	1h=1500F 12h=1500F 48hx1500F 144hx1500F	4 500F 18 000F 72 000F 216 000F
	Total General			**216.000F**

Arrêtée la présente facture a la somme de : Deux cents seize mille francs CFA

Signature

Ets. Rmd-Evolution-Service ; Quartier :Paris Congo ; Email :rmdevolution@gmail.com — Page 1



Date : 28/03/2018

BON POUR N° 02

MAHAMAT BICHARA
Issak

28 000,00 DA
Vingt-huit mille dinards

RESFA FIRST SMART POWER

Appendix

وكالة أبو عزيزة للسفر

AGANCE ABOU AZIZA POUR LE VOYAGE

Bureau d'abéché مكتب أبشة

هاتف TELE

66353533/66108860/66084422
66801011/66333475/66228884
99252080/99200030/95513441
91292008/91208478/90374444

تذكرة سفر

NOM MAHAMAT BICHARA ISSAK الاسم

رقم المقعد N° Chaise	التاريخ : Date	مواعيد القيام Depart	رقم الباص N° De bus	قيمة التذكرة Somme
14	16/4/2021		8	25000 Fa

CONDITION:
1. TOUT CE QUI EST INFLAMEL EST INTERDI
2. L'AGANCE N'EST RESPONSABLE DE PERTE DES BAGAGES NON PESER TOUT OBJET DE VALEUR

ملحوظة عامة :
١. يمنع حمل جميع أنواع المتفجرات والأسلحة الغير شرعية .
٢. الوكالة ليست مسؤولة عن الأشياء الغير مؤجرة .
٣. كل الأشياء القيمة وباهظة الثمن على مسؤولية صاحبها .

وكالة أبو عزيزة للسفر

AGANCE ABOU AZIZA POUR LE VOYAGE

Bureau d'abéché مكتب أبشة

هاتف TELE

66353533/66108860/66084422
66801011/66333475/66228884
99252080/99200030/95513441
91292008/91208478/90374444

تذكرة سفر

NOM MAHAMAT BICHARA ISSAK الاسم

رقم المقعد N° Chaise	التاريخ : Date	مواعيد القيام Depart	رقم الباص N° De bus	قيمة التذكرة Somme
1	21/4/2021		4	25000 Fa

CONDITION:
1. TOUT CE QUI EST INFLAMEL EST INTERDI
2. L'AGANCE N'EST RESPONSABLE DE PERTE DES BAGAGES NON PESER TOUT OBJET DE VALEUR

ملحوظة عامة :
١. يمنع حمل جميع أنواع المتفجرات والأسلحة الغير شرعية .
٢. الوكالة ليست مسؤولة عن الأشياء الغير مؤجرة .
٣. كل الأشياء القيمة وباهظة الثمن على مسؤولية صاحبها .
٤. الالتزام بالمواعيد المحددة في التذكرة .

وكالة أبو عزيزة للسفر

AGANCE ABOU AZIZA POUR LE VOYAGE

Bureau d'abéché مكتب أبشة

هاتف TELE

66353533/66108860/66084422
66801011/66333475/66228884
99252080/99200030/95513441
91292008/91208478/90374444

تذكرة سفر

NOM MAHAMAT BICH... الاسم

رقم المقعد N° Chaise	التاريخ : Date	مواعيد القيام Depart	رقم الباص N° De bus	قيمة التذكرة Somme
42	8/4/2021		9	25000 F

CONDITION:
1. TOUT CE QUI EST INFLAMEL EST INTERDI
2. L'AGANCE N'EST RESPONSABLE DE PERTE DES BAGAGES NON PESER TOUT OBJET DE VALEUR

ملحوظة عامة :
١. يمنع حمل جميع أنواع المتفجرات والأسلحة الغير شرعية .
٢. الوكالة ليست مسؤولة عن الأشياء الغير مؤجرة .
٣. كل الأشياء القيمة وباهظة الثمن على مسؤولية صاحبها .
٤. الالتزام بالمواعيد المحددة في التذكرة .

وكالة أبو عزيزة للسفر

AGANCE ABOU AZIZA POUR LE VOYAGE

Bureau d'abéché مكتب أبشة

هاتف TELE

66353533/66108860/66084422
66801011/66333475/66228884
99252080/99200030/95513441
91292008/91208478/90374444

تذكرة سفر

NOM MAHAMAT BICHARA ISSAK الاسم

رقم المقعد N° Chaise	التاريخ : Date	مواعيد القيام Depart	رقم الباص N° De bus	قيمة التذكرة Somme
32	3/4/2028		7	25000 FCFA

CONDITION:
1. TOUT CE QUI EST INFLAMEL EST INTERDI
2. L'AGANCE N'EST RESPONSABLE DE PERTE DES BAGAGES NON PESER TOUT OBJET DE VALEUR

ملحوظة عامة :
١. يمنع حمل جميع أنواع المتفجرات والأسلحة الغير شرعية .
٢. الوكالة ليست مسؤولة عن الأشياء الغير مؤجرة .
٣. كل الأشياء القيمة وباهظة الثمن على مسؤولية صاحبها .

Electronique

Issue date:	**11 MARS 18**
Airline booking ref:	**TK/U48W6Z**
Compagnie Emettrice:	**TURKISH AIRLINES**
Numéro de billet:	**235-2494334097**

Bagages

Passager	**Mahamat Bichara Issak (ADT)**	Agence	**ONAT TLEMCEN** **RUE 1ER NOVEMBRE** **TLEMCEN** **TLEMCEN**
		Téléphone	**43271680/043271650/60**
		IATA	**03245911**
		Agent	**0002**

Itinéraire

Tuesday 20 March 2018

De	À	Vol	Classe	Date	Départ	Arrivée	Résa (1)	NVAV(2)	NVAP(3)	Fin d'enregistrement	Bagages (4)	Siège
ALGIERS	**ISTANBUL** Terminal I	TK0654	Q	20Mar	**11:05**	**16:35**	Ok	20Mar	20Mar		2PC	

Opéré par	TURKISH AIRLINES	**Base Tarif**	QB4XP6M		
		Commercialisé par	TURKISH AIRLINES		
Equipment	Boeing 737-800 (Winglets)			**Durée**	03:30 (Non Stop)
Flight Meal	Meal				

Tuesday 20 March 2018

De	À	Vol	Classe	Date	Départ	Arrivée	Résa (1)	NVAV(2)	NVAP(3)	Fin d'enregistrement	Bagages (4)	Siège
ISTANBUL Terminal I	**N'DJAMENA**	TK0665	Q	20Mar	**18:50**	**02:50**	Ok	20Mar	20Mar		2PC	

		Base Tarif	QB4XP6M		
Opéré par	TURKISH AIRLINES	**Commercialisé par**	TURKISH AIRLINES		
Equipment	Boeing 737-900	**Arrivée Jour+1**		**Durée**	10:00 (1 Stop)
Stop	Nsimalen Intl				
Flight Meal	Meal				

Sunday 01 July 2018

De	À	Vol	Classe	Date	Départ	Arrivée	Résa (1)	NVAV(2)	NVAP(3)	Fin d'enregistrement	Bagages (4)	Siège
N'DJAMENA	**ISTANBUL** Terminal I	TK0665	Q	01Jul	**03:10**	**11:10**	Ok	01Jul	01Jul		2PC	

		Base Tarif	QB4XP6M		
Opéré par	TURKISH AIRLINES	**Commercialisé par**	TURKISH AIRLINES		
Equipment	Boeing 737-900			**Durée**	06:00 (Non Stop)
Flight Meal	Meal				

Sunday 01 July 2018

De	À	Vol	Classe	Date	Départ	Arrivée	Résa (1)	NVAV(2)	NVAP(3)	Fin d'enregistrement	Bagages (4)	Siège
ISTANBUL Terminal I	**ALGIERS**	TK0651	Q	01Jul	**13:10**	**15:00**	Ok	01Jul	01Jul		2PC	

		Base Tarif	QB4XP6M		
Opéré par	TURKISH AIRLINES	**Commercialisé par**	TURKISH AIRLINES		
Equipment	Airbus Industrie A330-200			**Durée**	03:50 (Non Stop)
Flight Meal	Meal				

(1) Ok = **confirmé** (2)NVAV= **Non valide avant** (3)NVAP= **Non valide après**(4) **Chaque passager est autorisé à enregistrer en soute un poids ou un nombre de bagages sans frais supplémentaires, comme indiqués ci-dessus au niveau de la colonne bagages.**

A l'enregistrement, vous devez présenter une pièce d'identité.

Reçu de paiement

Nom	**: Mahamat Bichara Issak (ADT)**
Numéro de billet	: 235 2494334097
Mode de paiement	: CASH

Taxes	: DZD 1300XE	DZD 20DZ	DZD 1500DZ
	DZD 1422TR	DZD 2167IB	DZD 4767IP
	DZD 4334ZG	DZD 1626TD	DZD 2167BX
	DZD 1300G6	DZD 2167I3	
Surcharges Appliquées Par La Compagnie	: DZD 28730YR		
Montant total	: DZD 132020		
Compagnie Emettrice et date	: TURKISH AIRLINES 11Mar18		
Restriction(s)/Endossements	: NONEND/TK ONLY		

Tarif valable uniquement si le billet est utilisé intégralement et dans l'ordre séquentiel des coupons.

L'émission CO2 moyenne calculée est 999.02 Kg/personne
Source : calculateur d'émission de CO2 fourni par ICAO
http://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx

Notre compagnie vous souhaite un agréable voyage.
Ce document établit la création de votre (vos) billet(s) électronique(s) dans nos systèmes informatiques. Il ne constitue pas un titre de transport.
Pour plus d'informations, contacter nous.

Le transport et les autres services fournis par le transporteur sont soumis aux conditions générales de transport qui sont incluses ici, en référence. Ces conditions peuvent être obtenues auprès de la compagnie émettrice du billet. Le mot 'Billet Electronique' désigne l'itinéraire/reçu émis par le transporteur ou pour son compte, tout document électronique s'y rapportant et, le cas échéant, un document d'embarquement. Les passagers effectuant un voyage vers une destination finale ou incluant un arrêt dans un autre pays que celui de départ sont informés que les conventions connues sous le nom de convention de Montréal, ou convention de Varsovie qui l'a précédée, incluant ses amendements (le système convention de Varsovie), peuvent s'appliquer à l'ensemble du voyage, y compris toute partie de celui-ci effectuée dans un même pays. Pour ces passagers, la convention applicable, incluant les contrats spécifiques de transport liés à tout tarif applicable, régit et peut limiter la responsabilité de la compagnie. Ces conventions régissent et peuvent limiter la responsabilité des transporteurs aériens en cas de décès ou de préjudice corporel, de perte ou de dommages causés aux bagages, ou de retard.

Certaines matières ou objets, dits « marchandises dangereuses », tels que les aérosols, les feux d'artifices et les liquides inflammables sont strictement interdits à bord. Si vous ne comprenez pas ces restrictions, veuillez-vous adresser à votre compagnie aérienne pour plus d'informations.

CLICK THE FOLLOWING LINK TO ACCESS YOUR ONLINE ITINERARY:
https://www.checkmytrip.com/CMTservlet?R=LXXKYR&L=GB&N=MAHAMAT BICHARA

ELEKTRONİK BİLET YOLCU SEYAHAT BELGESİ
ELECTRONIC TICKET PASSENGER ITINERARY

TURKISH AIRLINES

Düzenlendiği Tarih / Issue Date	: 20MART18 / 20MAR18
Düzenleyen / Issuance	: QGX/CE/THYAIRPORT
Seri No / Serial No	: 3494260

462 Sıra No.lu VUK Genel Tebliği uyarınca elektronik olarak imzalanan ve tevsik edici belge olarak kullanılabilen mail e-biletlere, biletin düzenlenmesinden itibaren en geç 72 saat içerisinde [illegible] adresinden erişilebilmektedir. Acente tarafından düzenlenen biletlere ilişkin faturaların acenteden temin edilmesi gerekmektedir.

OTOMATİK BİR MESAJDIR, LÜTFEN YANITLAMAYINIZ.
THIS DOCUMENT IS AUTOMATICALLY GENERATED.
PLEASE DO NOT RESPOND TO THIS MAIL.

THY Genel Müdürlüğü Atatürk Havalimanı 34149 - İstanbul

Büyük Mükellefler Vergi Dairesi
8760047464

Tel : +90(212) 463 63 63

+90(212) 444 0 849
+90(850) 333 0 849
www.thy.com

Yolcu İsmi / Passenger Name	: MAHAMATBICHARA ISSAK
Bilet No / Ticket Number	: 2352341601326
Rezervasyon No / Booking Ref.	: U48W6Z
Adres / Address	:

Firma İsmi / Company Name	:
Vergi Dairesi - Hesap No / Tax Office - Account No	:
T.C. Kimlik Numarası / Identification No	:
Kısıtlama / Endorsmen/Restr.	: DZD15050NON-REF.RSDEMDDZD76.DUNOELI G.
Ödeme / Payment	: CASH
Esas ücret / Base Fare	: DZD 109070
Vergi / Tax	: 21240CP 70YR 1520DZ
Toplam / Total	: DZD 51380A

Den/A	Taşıyıcı	Uçuş	Snf.	Tarih	Saat	Ücret Esası	Bagaj	Bilet Durumu	Kupon Durumu	Önce Geçerli	Sonra Değil
From/To	Carrier	Flight	Cls	Date	Time	Fare Basis	Bag	Tkt St	Cpn St	Nvb	Nva
ALGIERS/ALG ISTANBUL/IST	TK	0652	H	23MART / 23MAR	1650 2215	HB	2P	OK	OPEN	23MART / 23MAR	23MART / 23MAR
*ISTANBUL/IST NDJAMENA/NDJ	TK	0665	H	24MART / 24MAR	1850 0250	HB	2P	OK	OPEN	24MART / 24MAR	24MART / 24MAR
NDJAMENA/NDJ ISTANBUL/IST	TK	0665	Q	01TEMMUZ / 01JUL	0310 1110	QB	2P	OK	OPEN	01TEMMUZ / 01JUL	01TEMMUZ / 01JUL
ISTANBUL/IST ALGIERS/ALG	TK	0651	Q	01TEMMUZ / 01JUL	1310 1500	QB	2P	OK	OPEN	01TEMMUZ / 01JUL	01TEMMUZ / 01JUL

HOMER Energy, LLC
1790 30th St
Suite 100
Boulder, CO 80301
United States
Email: bookkeeper@homerenergy.com

Invoice

Invoice #	5152
Billed On	Apr 20, 2018
Terms	On-Receipt
Due On	Apr 20, 2018

Bill To

Mahamat Bichara
Ndjamena
Chad

PAID on Apr 20, 2018

$185.00 USD

Date	Description	Qty	Price	Subtotal
Apr 20 – May 20, 2018	Monthly license subscription	1	$185.00	$185.00

Subtotal	$185.00
Total	$185.00
Paid	($185.00)
Amount Due	**$0.00**

Payments

Apr 20, 2018 $185.00 Payment from MasterCard ··· 5898

Notes

Subscriptions invoiced: (1) HOMER Pro Standard monthly license with package: Expert (Order 22329)

All amounts in United States Dollars (USD)

Terms and Conditions: All prices are in US Dollars. Prices do not include Tax/VAT. Taxes are the responsibility of the customer.

HOMER Energy, LLC
1790 30th St
Suite 100
Boulder, CO 80301
United States
Email: bookkeeper@homerenergy.com

Invoice

Invoice #	5160
Billed On	May 20, 2018
Terms	On-Receipt
Due On	May 20, 2018

Bill To

Mahamat Bichara
Ndjamena
Chad

PAID on May 20, 2018

$185.00 USD

Date	Description	Qty	Price	Subtotal
May 20 – Jun 20, 2018	Monthly license subscription	1	$185.00	$185.00

Subtotal	$185.00
Total	$185.00
Paid	($185.00)
Amount Due	**$0.00**

Payments

May 20, 2018 $185.00 Payment from MasterCard ··· 5898

Notes

Subscriptions invoiced: (1) HOMER Pro Standard monthly license with package: Expert (Order 22329)

All amounts in United States Dollars (USD)

Terms and Conditions: All prices are in US Dollars. Prices do not include Tax/VAT. Taxes are the responsibility of the customer.

HOMER Energy, LLC
1790 30th St
Suite 100
Boulder, CO 80301
United States
Email: bookkeeper@homerenergy.com

Invoice

Invoice #	5169
Billed On	Jul 2, 2018
Terms	On-Receipt
Due On	Jul 2, 2018

Bill To

Mahamat Bichara
Ndjamena
Chad

PAID on Jul 2, 2018

$185.00 USD

Date	Description	Qty	Price	Subtotal
Jul 2 – Aug 1, 2018	Monthly license subscription	1	$185.00	$185.00

Subtotal	$185.00
Total	$185.00
Paid	($185.00)
Amount Due	**$0.00**

Payments

Jul 2, 2018 $185.00 Payment from MasterCard ··· 5898

Notes

Subscriptions invoiced: (1) HOMER Pro Standard monthly license with package: Expert (Order 22329)

All amounts in United States Dollars (USD)

Terms and Conditions: All prices are in US Dollars. Prices do not include Tax/VAT. Taxes are the responsibility of the customer.