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

Master Thesis

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

ENERGY POLICY

Presented by

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

SOCIO-ECONOMIC FEASIBILITY STUDY OF BLOCKCHAIN BASED PEER-TO-PEER ENERGY SYSTEM IN RURAL AFRICA: Case Study Algeria

A thesis submitted to the Pan African University Institute of Water and Energy Sciences (including Climate Change) in partial fulfilment of the requirements for the degree of Master of Science in Energy (Policy option).

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ABSTRACT

Algeria is the Saharan Africa is still very far behind in terms of access to modern energy. 548 million people, which is 47% of the population still lack access to electricity in 2018 and unreliability of electricity supply is a major problem in the region. Furthermore, high disparity also occurs between urban and rural situation. The lack of investment in rural electrification is mainly due to the lack of financial resources allocated to the sector and also to the technical feasibility since many African villages are in remote area, far from the national grid and highly dispersed which make difficult the investment in grid extension. In order to address this challenge, decentralized energy systems harnessed from local available energy resources has been identified as one of the most promising approach. However, the implementation of mini-grid systems in the region is facing many challenges such as the lack of sustainability due to the low purchasing power of the population. In order to respond to that issue, the emergence of new digital technologies like artificial intelligence (AI), Internet of things (IoT) and particularly blockchains can have a very promising considerable impact in energy access finance. Besides, the development of those various smart energy has allowed the promotion of effective management of the energy demand. At the heart of this innovative energy management system is the Peer-to-peer energy sharing concept which is a decentralized electricity trade between prosumers and consumers. The International Renewable Energy Agency emphasized that trading based on P2P models makes renewable energy more accessible, empowers consumers and allow them to make better use of their energy resources. The integration of the blockchain in the P2P mechanism can lead to the creation of new innovative marketplaces more transparent, secured and tamper resistant. In the recent years, the P2P trading platforms has been developed considerably in the world and many projects has already been implemented. However, such technology is just at its very early stage in SSA although it is a great potential to improve the electricity access. In addition, the descent on the ground is useful in order to know case by case the economic, social and environmental situations of the population which allows the validity of this project. Therefore, this research aims at conducting a socio-economic feasibility study of blockchain based peer-to-peer energy off-grid system in a rural Sub-Saharan Africa.

RÉSUMÉ

L'Afrique subsaharienne est encore très en retard en termes d'accès à l'énergie moderne. 548 million de personnes, soit 47% de la population, n'ont toujours pas accès à l'électricité en 2018 et le manque de fiabilité de l'approvisionnement en électricité est un problème majeur dans la région. En outre, il existe également une forte disparité entre la situation urbaine et rurale. Le manque d'investissement dans l'électrification rurale est principalement dû au manque de ressources financières allouées au secteur et aussi à la faisabilité technique puisque de nombreux villages africains sont en zone reculée, loin du réseau national et très dispersés ce qui rend difficile l'investissement dans le réseau. extension. Afin de relever ce défi, les systèmes énergétiques décentralisés exploités à partir des ressources énergétiques locales disponibles ont été identifiés comme l'une des approches les plus prometteuses. Cependant, la mise en œuvre des systèmes de mini-réseaux dans la région est confrontée à de nombreux défis tels que le manque de durabilité dû au faible pouvoir d'achat de la population. Afin de répondre à cette problématique, l'émergence de nouvelles technologies numériques comme l'intelligence artificielle (IA), l'Internet des objets (IoT) et en particulier les blockchains peuvent avoir un impact considérable très prometteur dans le financement de l'accès à l'énergie. Par ailleurs, le développement de ces différentes smart energy a permis la promotion d'une gestion efficace de la demande énergétique. Au cœur de ce système innovant de gestion de l'énergie se trouve le concept de partage d'énergie Peer-to-peer qui est un commerce d'électricité décentralisé entre les prosommateurs et les consommateurs. L'Agence internationale pour les énergies renouvelables a souligné que le commerce basé sur des modèles P2P rend les énergies renouvelables plus accessibles, responsabilise les consommateurs et leur permet de mieux utiliser leurs ressources énergétiques. L'intégration de la blockchain dans le mécanisme P2P peut conduire à la création de nouvelles places de marché innovantes plus transparentes, sécurisées et infalsifiables. Ces dernières années, les plateformes de trading P2P se sont considérablement développées dans le monde et de nombreux projets ont déjà été mis en œuvre. Cependant, cette technologie n'en est qu'à ses débuts en ASS, bien qu'elle représente un grand potentiel pour améliorer l'accès à l'électricité. En plus, la desente sur terrain est utile afin de connaitre de cas par cas des situations economique, social et environmental des population qui permet la validite de ce projet. Par conséquent, cette recherche vise à mener une étude de faisabilité socio-économique du système d'énergie hors réseau peer-to-peer basé sur la blockchain dans une zone rurale d'Afrique subsaharienne.

DEDICATION

I dedicate this work to my family especially my parents, my sister and my little brother without whom none of my success would be possible

STATEMENT OF THE AUTHOR

I, Hasiniaina ROJOSOA hereby declare that this thesis represents my original work and that it has not been submitted to another institution for a degree, diploma or certificate.

I also declare that all words and ideas from other work presented in this thesis have been duly cited and referenced in accordance with academic rules and regulations. I have done everything to avoid plagiarism.

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ACKNOWLEDGMENT

A big thank you to the Lord for his love, his mercy, his advice, for the path he guides me and for making this dream come true.

I sincerely thank the African Union Commission for providing me with such an opportunity to pursue the incredible Master in Energy Engineering at PAUWES (the Institute of Water and Energy Sciences), Algeria.

I am sincerely grateful to my supervisor, Dr Erick Tambo, whose all instructions, guidance and constant help led to the success of this thesis. Special thanks also go to Dr. Emmanuel Cheo and Dr. Arouna DARGA for their assistance and advices. I also particularly appreciate all the invaluable contributions and contributions of Axel Ngedia-Nguedoung and Mirana Njakatiana Andriarisoa who have helped me with the practical part of my work.

A deep gratitude goes to my friends and family for their undying love and support throughout this journey

LIST OF ABBREVATIONS

IEA	International Energy Agency
RES	Renewable Energy Sources
OEDC	Organization for Economic Co-operation and Development
IRENA	International Renewable Energy Agency
SSA	Sub Saharan Africa
AMDA	Africa Mini-grid Developers Association
EEA Africa	Energy and Environment Partnership Programme
Iot	Internet of Things
AI	Artificial Intelligent
P2P	Peer-to-Peer
SDG	Sustainable Development Goal
MTF	Multi-Tier Framework
SHS	Solar Home System
VPP	Virtual Power Plant Management
MCP	Market Cleaning Price
ICT	Information and Communication Technology
OPF	Optimal Power Flow
ADMM	Alternate Direct Methods of a Multiplied Algorithm
USD	United States Dollar
PEDEEP	Programme de developpement des energies renouvelables et d'efficacites energetique
ICAEN	Instituto Catalan de Energia
CDER	Centre de Developement des Energies Renouvelables
PAED	Plan d'Action en faveur de l'Energie Durable
LED	Light Emitting Diod

APC	Assemblée Populaire Communale
MS-Project	Microsoft Spftware – Project
PERT	Program Evaluation and Review Technique
MIT	Massachusetts Institut of Technology
HBR	Harvard Business Review
WWII	World War 2
GDP	Global Domestic Product
ONAEA	Offiche National d’Aplhabetisation et d’enseignement des Adultes
CEO	Chef Executive officier
ESMAP	Energy Sector Management Assistant Program
RMSPE	Root Mean Squared Percent Error

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I. INTRODUCTION

I.1 Background of the study

Promoting sustainable development and combating climate change are now an integral part of energy planning, analysis and policy making (IEA, 2020). Energy companies are means used by each country to improve the National and International economy. Global energy consumption increased by 2.1% in 2017 (IEA, 2017); In 2019, the US Energy Information Administration (EIA) predicts that expected growth in Asia by 2050 will be 50%. Since these demands are unlikely to be met by conventional energy systems, the world is moving towards renewable energy (RES) systems supported by cyber-physical technologies (H. A. Muller, 2017). Therefore, climate change increases the need and necessity to reduce dependence on resources, many countries aim to increase dependence on renewable energy. In this case, there has been an increase in the share of renewables in the total energy of the world as a whole. The shift from conventional energy sources to renewables is clear, as it was revealed in 2018, 30% of the UK's gross electricity consumption was generated by RES (according to the Green Match UK report on renewable energies). Today, sustainable energy is becoming one of the solutions to mitigate climate change, which accounts for two thirds of total greenhouse gases. According to the United Nations Sustainable Development Goal 7, access to affordable, reliable, sustainable and modern energy should be achieved in Agenda 2030. Yet in Africa, the goal in Agenda 2036 has been set to ensure inclusive and sustainable economic growth through a revival of the renewable energy sector.

Furthermore, the world's electricity consumption has increased by 56% since 1973 (BP Statistical Review of World Energy, June 1988), which means that the growth of electricity is being exploited; in fact, the share of primary energy in the world contributes to its production is increasing from time to time. However, Electricity ensures the economic development of every country in the world. Its relative importance increases with technical progress, industrialization and the need for modern comfort. The increase in its production is synonymous with the improvement of its quality of life and the creation of wealth. According to IEA/OEDC, the world's gross electricity production in 2016 was 25,082 TWh, and sin 2018, world gross electricity production was 3.9% higher than 2016 and 2017, this is means that industry was still the largest end-use sector for electricity consumption. As a result, access to electricity has been growing in recent years and the number of private individuals has increased 1 billion in 2016 (and 1.2 billion in 2010) to about 840 million today (IRENA, 2019). Since 2010, the increase has spread to all continents such as Bangladesh, India, Myanmar and India. In addition, the rate of electrification in the world has reached 89% and an additional 153 million people have been connected to electricity each year (IEA, 2019). But the case of Africa 573 million people still lives in the dark, especially in sub-Saharan and in the region at low altitude in Africa. Sub-Saharan Africa is also facing a marked energy divide: more than 65% of the population still has no access to electricity and more than 80% use traditional fuels (wood, charcoal) for cooking (Acceleration of Energy Transition in Africa, 2019). Until recently, renewable energy depended on private sources that were considered capable of providing only basic energy services - for individual houses, large or small communities - but financial resources and lack of investment remain a big problem. And also, the lack of access to human capital, planning difficulties and donor dependence, weak rural markets are the economic issue especially in African village Rural.

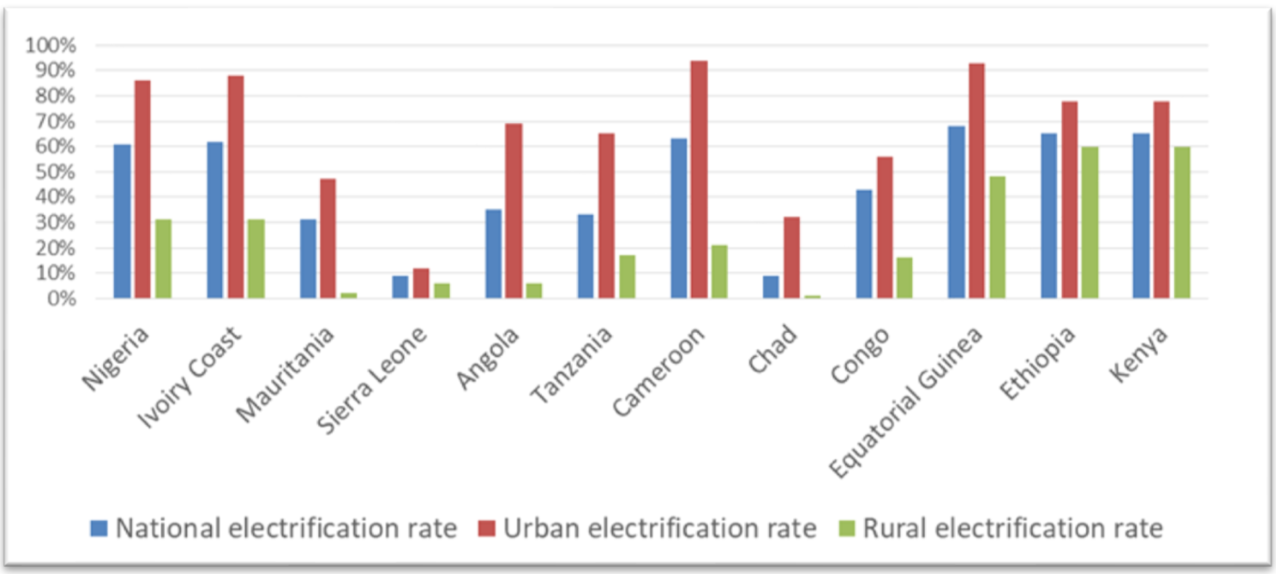


Figure 1:Electrification rates of some Sub-Saharan African (SSA) countries

To meet the challenge, the mini-grid was identified as one of the most efficient solution to achieve the goal in 2030. The International Energy Agency (IEA) provides that mini-grids and autonomous systems outside network will play a key role in extending electricity to many rural areas in Sub-

Saharan African (SSA) countries that currently do not have access to national grids. He estimates that 140 million of the 315 million rural Africans who will have access to electricity by 2040 will to meet the challenge, the mini-grid has been identified as one of the most efficient solutions to achieve the goal by 2030. The International Energy Agency (IEA) predicts that mini-grids and stand-alone systems off-grid will play a key role in extending electricity. Many rural areas in Sub-Saharan African (SSA) countries that currently do not have access to national networks. He estimates that 140 million of the 315 million rural Africans who will have access to electricity by 2040 will be served by mini-grids. To help achieve this level of access, which will require 100,000 to 200,000 mini-grids, AMDA can play a central role in advocating for enabling policies and regulations, leveraging private funding, and implementing initiatives field projects (Catherine Morris, 2018). As a result, the consumer cost of electricity from mini-grids remains higher than national grid tariffs, which are generally subsidized and do not reflect costs. (EEP Africa, 2020). In order to solve the problem, energy exchange models are proposed to overcome technical challenges and market barriers, and to foster the adoption of disruptive technologies such as the Internet of Things (IoT), artificial intelligence (AI) and in particular blockchain. The use of the energy exchange system in “Peer-to-Peer” (P2P) mode promotes decentralization, security, scalability and systems integration.

I.2 Problem statement

As the developed world continues to advance technologically and fill the gaps in existing “green” economic, financial and environmental systems, while consequently improving the socio-economic indices of their respective countries and citizens; an introspection is lacking that is out of place when it comes to examining the challenges facing its third world counterpart, Africa (June Levi-Oguike & Diego Sandoval, 2019). The continent of Africa continues to struggle with problems related to energy poverty and general access to energy, which verifies, certain indicators show that a large majority still does not have access to modern energy services, affordable and reliable (Etienne Ntagwirumugara, 2019). The main gaps are indicated as insufficient or deficient socio-environmental policies, a gap or insufficient investment in this sector especially on technology, an unstable model framework for access to energy using relative trade exchanges to the economic, social and environmental environment.

I.3 Research questions

Sub-questions:

Which business model dynamic approves the socio-economic feasibility of blockchain based peer-to-peer energy system and how do they affect the electricity market.?

Research questions:

1. How to Assess the potential economic, social and environmental impact of developing blockchain-based P2P energy trading;
2. How to assess the customer/prosumers perception and acceptance of the technology;
3. How to identify the electricity situation with mini-grid system;
4. How does this give us a comparative advantage of blockchain-based P2P energy trading between the two other alternatives: the simulated value of the model and the historical value of a centralized energy system.

I.4 Aim and research of objectives

Main objective

The main objective of the study will be aims at conducting a socio-economic feasibility study of blockchain based peer-to-peer energy off-grid system in a rural Africa.

Specific objectives

- To assess the potential economic, social and environmental impact of developing a blockchain-based P2P energy trading;
- To assess the customer / prosumers perception and acceptance of the technology;
- To identify the electricity situation with mini-grid system;
- To conduct a comparative a comparative advantage of blockchain-based P2P energy trading between the two other alternatives: the simulated value of the model and the historical value of a centralized mini-grid energy system.

I.5 Significance of the study

The evolution of access to modern electricity fell to less than 1.1 billion in 2016. While the extension of the central network continues to be the driving force behind the acceleration of access to electricity, decentralized solutions based on renewable energies have gained ground, accounting for 6% of new electrical connections since 2000 (International Energy Agency (IEA), 2017). In addition, the innovation of the economic model, the fall in the cost of electricity and decentralized renewable energy systems have favored access to energy, particularly in rural areas of developing countries.

According to Goldemberg et al, sustainable energy services are "environmentally friendly, safe, affordable, practical, reliable and equitable", as well as "the energy service having an impact in terms of socio-economic and environmental considerations" (Goldemberg et al, 2001). In addition, the success of new conceptualizations of energy projects lies between the acceptability, ease of use and efficiency of the technology taking into account the specific socio-economic and cultural context of the project (Annecke and W. Monitoring, 2008). Despite the progress and evolution of different approaches to assess the sustainability of energy access, technological and economic considerations remain a priority (Kumar et al, 2009).

The results of this study will also help the government and all those in charge of the energy sector in Algeria in its pursuit of the vision of the digitalization and expansion of energy project including electricity in Algeria, as well as different stakeholders on how to engage in community electrification projects. In addition, this study will contribute to the achievement of the African Union's Agenda 2063 including “access to energy for all”. And also, contribute to the improvement of the economic sector in the country studied. Finally, it is an instrument used by the government to support energy policy with the aim of moving towards global investment in this sector.

II. LITERATURE AND TECHNICAL REVIEW

The world of today is gradually converging towards the globalization of technology, especially in the energy sector. The future of energy depends on indefinite renewable resources in increasingly shared systems. The blockchain technology in P2P mechanism is a relevant innovation to ensure this future. These mechanisms can side with renewable energies and lead to the emergence of prosumers (producers and consumers) who are capable of both producing and consuming.

This section presents the work of the various authors devoted to Digitalization for Energy Access in Sub-Saharan Africa, Review of Socio-economic and technological developments, Current scenario in the energy market, and then current status of the application of blockchain technology in the electric power sector.

II.1 Digitalization for Energy Access in Sub-Saharan Africa

II.1.1 Introduction

Currently, Africa is gradually entering the application of crypto-currencies such as Bitcoin. It can solve some problems such as obstacles to the exchange of goods and services between different currencies, obstacle on time constraint, ... etc. They also some private banks in South Africa like BSA, Frist National Rand, Investec, Nedbank, Standard Bank and South African Reserve Bank which are already adopting blockchain and other Public blockchains. The advantage of using this application is to reduce the cost and improve the speed of asset exchange. In addition, Kenya is also already introducing BitPesa, a digital platform that transacts digital currency called "Bitcoin" in local African currency without middleman.

II.1.2 Status of the energy access in Sub-Saharan Africa

Electrification in Sub-Saharan Africa (SSA) is an obstacle to development. Between 2000 and 2017 we noticed an evolution which went from 23% to 43% (IEA, 2018), in parallel with the number of people without access to electricity. Currently, 602 million people have an emission for the inaccessibility of electricity so in nearly 80 million in 2000. This scenario has been rethought in the Development Goals (SDGs) 7 in order to achieve universal access to electricity by 2030. Consequently, some African countries are unable to implement the electrification policy due to the weakness of the Government. For example, in Ghana, South Africa and East Africa, the government has not been able to provide financial assistance to this sector, while actions taken by officials are not having an impact. positive on the living condition of the population (Bhattacharyya, 2012). Thus, from 2013, certain improvements have been made, while household access to electrification has been increased since 2000; however, in 2017 it was decreased due to the increase in population (Figure 2).

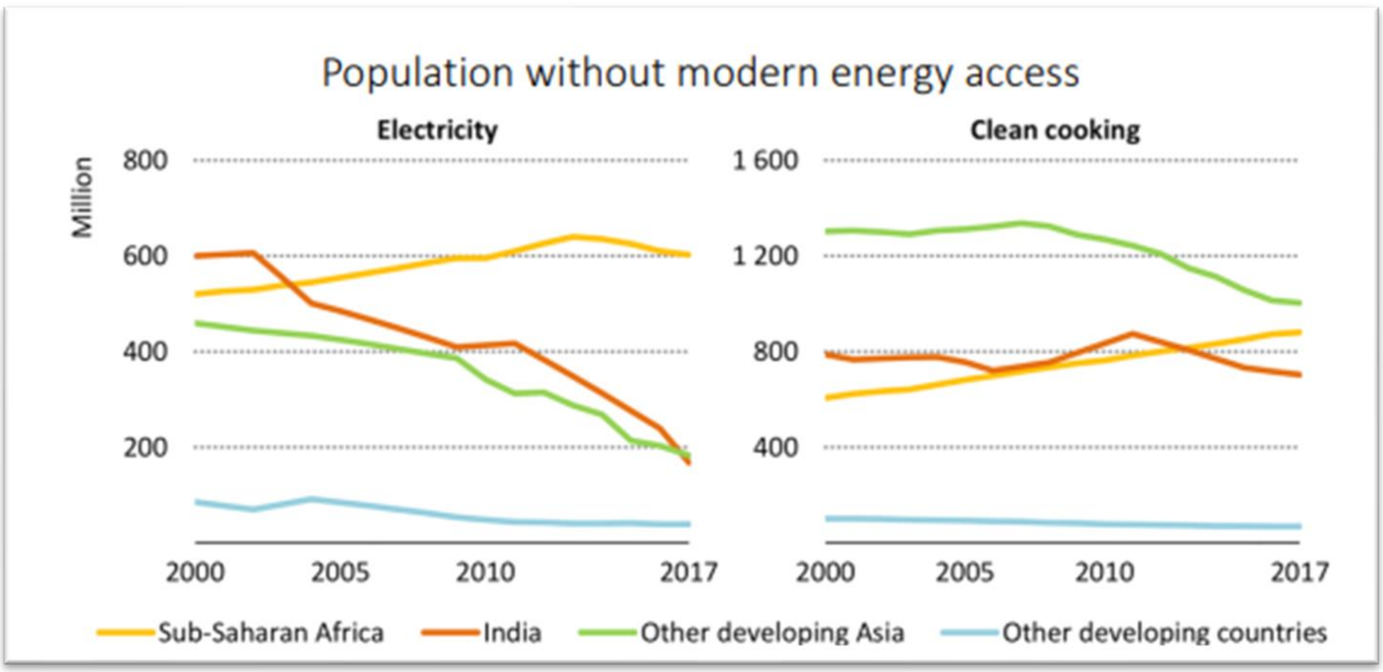


Figure 2:Population without modern energy access - Source: International Energy Agency (2018)

Figure (3) on the right shows the situation of the population without access to electricity in SSA while the first three are in Nigeria, Democratic Republic of Congo and Ethiopia.

Figure (3) on the left shows the improvements in the national electricity access rate between 2010 and 2017. The figures inside the bars represent the percentage points gained over the period - Data source: International Agency for Energy (2018). Figure (3) as a whole focus on the trend with an additional 4.3 million people without access to electricity over the past year. Some countries like Kenya, Ethiopia, Tanzania and Nigeria have more electrified people from 2011, on the other hand some have been decreasing their electrification rate due to population increase. In Zimbabwe, Guinea-Bissau and Guinea is the precise example that they fail to keep up with the rate of increase like the others.

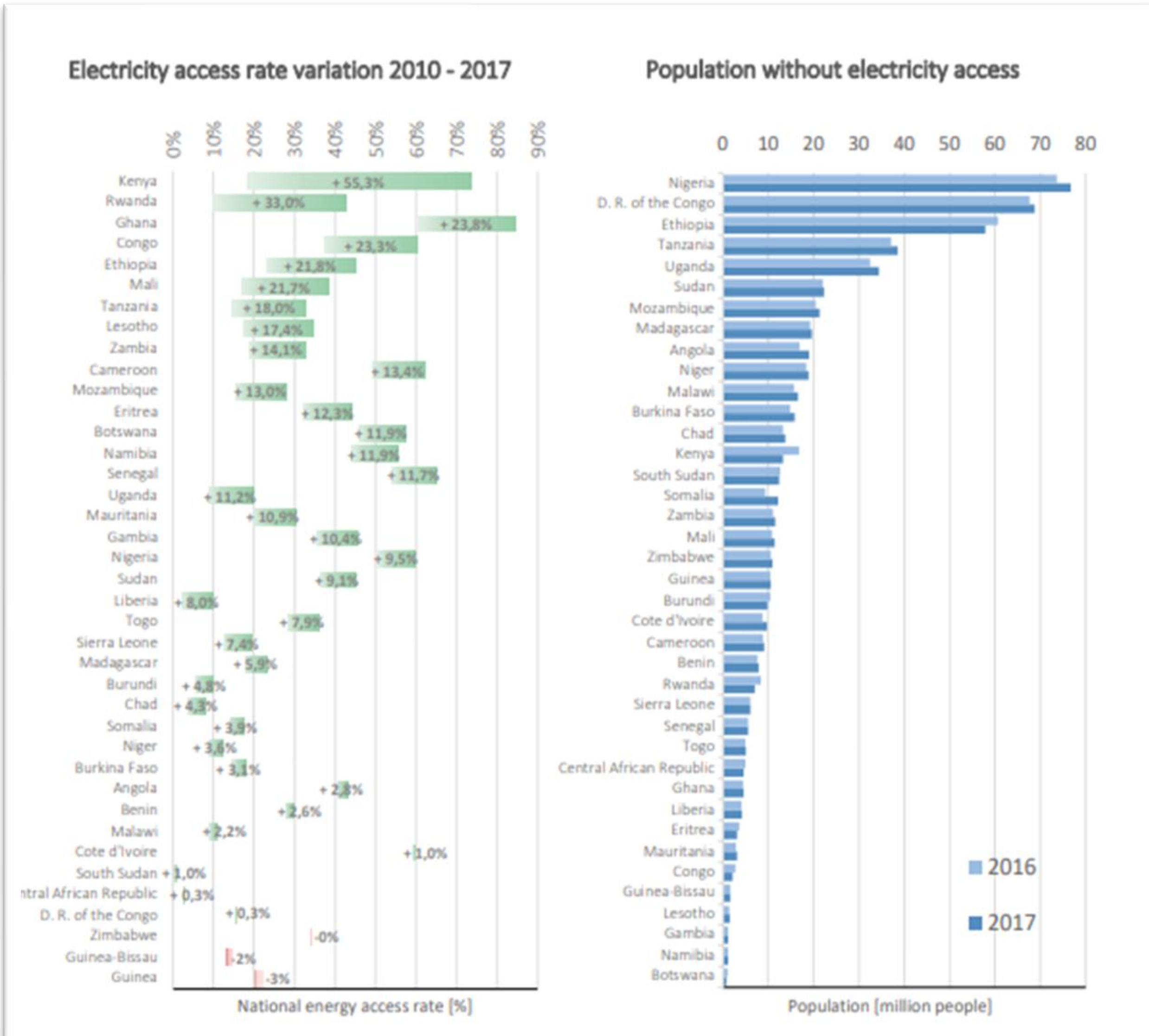


Figure 3:Numbers inside the bars represent the percentage points gained over the period - Data source: International Energy Agency (2018).

In addition, the improvement and the drunkenness in the electricity sector are focused in the urban areas than in the rural areas.

Households who live in the urban area can bear the higher cost and ready to pay due to the higher salary compared to the rural area. Therefore, most of the countries which is less than 1% of the rural population have basic access to electricity such as South Sudan, Democratic Republic of Congo, Guinea, Niger, Mauritania, Burkina Faso and in a few countries, it exceeds 20% (ESI Africa, 2018)

To be sure, we must look at these five criteria of information on the level of access to energy; there are the different type of devices capable of operating (Azimoh,2015)

- Service availability,
- Reliability,
- Quality,
- Financial accessibility,
- Legality
- Security.

And also, without neglecting the definition of access to electricity provided by the International Energy Agency (IEA) as the following: "access to sufficient electricity to supply a set of basic energy services - at least several bulbs, work lighting (like a flashlight), phone charging and a radio - with the service level capable of grow over time”.

II.1.3 *Technological* options available to provide access to electricity

It is necessary to understand the means of access to energy in terms of minimum requirement before imposing the types of technology that should be introduced. We see in the table …. below the different levels of energy access on the basis of the multi-level framework (MTF) of the World Bank for access to household electricity supply. Thus, the International Energy Agency has precise that level 2 is the minimum necessary for households to be considered electrified (Gibson, D., 2017).

Table 1: Multi-Tier Framework (MTF) for access to household electricity supply. The minimum power and energy ratings are indicative – particularly for Tier 1 and Tier 2 – as the efficiency of end-user appliances is critical to determining the real level of capacity required to provide a certain service. – Source: (ESMAP World Bank, 2015).

Attribute	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Minimum power*	3 W	50 W	200 W	800 W	2 kW
Minimum daily energy consumption*	12 Wh	200 Wh	1 kWh	3.4 kWh	8.2 kWh
Minimum services	Task lighting, phone charging, radio	Previous plus general lighting, air circulation, television	Previous plus food processing, washing machine	Previous plus refrigerator, iron	Previous plus air conditioner
Minimum duration	4 h/day 1 h/evening	4 h/day 2 h/evening	8 h/day 3 h/evening	16 h/day 4 h/evening	23 h/day 4 h/evening
Reliability	-	-	-	Max 14 disruptions/week	Max 3 disruptions/week of total duration <2h
Quality				Voltage fluctuation are safe for the appliances	
Affordability			Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
Legality				Bills are legally paid to the utility, prepaid card seller or authorized representative	
Health and safety				No past accidents and no perception of high risk in the future	

* With standard appliances. Super-efficient appliances provide higher services with lower

Here is the different type of the technology available to provide access to electricity:

❖ **Grid connection:** This system is really more profitable. Generally, it has provided the highest level of electricity supply, being the cheapest answer if there is a distribution network nearby, but its cost increases exponentially with distances and the network difficult to extend through difficult topographies. Additionally, this cost of electricity for low energy consumers is $ 1 / kWh and the initial cost of connecting new users can range from $ 266 to $ 2,100 per household (Climate scope, 2018a).

- **Mini and micro-grids**: The mini and micro-grids are operated from an energy storage system or from a back-up system by the combination of renewable energies and diesel generators. However, in the past year, many households have installed this system due to the low cost of solar PV technology and batteries. Currently, the cost is still too high in rural areas because of the difficulty and the scarcity to have for this technology (Climate scope, 2018a).
- **Solar Home System (SHS):** Another technology is solar home systems (SHS) which is the very efficient means for basic energy needs. Some companies in Africa plan to sell services such as solar kits to meet the energy needs of populations. At the same time, the modified cost of the energy sold can be used taking into account the lower energy required Figure ... "East AfriOca will become one of the largest markets for solar home systems, with total capital expenditures exceeding that of grid extensions. Microgrids are expected to play a larger role in West Africa, where some governments are developing ambitious deployment plans" (Climate scope, 2018a).
- **The Pico-solar:** and to finish, the Pico-solar supplies <10 W of energy precisely for the light and the charger of a mobile telephone. This is important even if the level of service that it gives is different by the minimum level elaborated. by the IEA. In addition, this system can improve energy services for low-income households and their cost is very accessible and affordable throughout sub-Saharan Africa (Climate scope, 2018a).

Figure (4) shows the trend of low energy consumers. On the left of Figure (4), we can see that low consumption consumers can rely on the national network without adding additional infrastructure such as network extensions. This assumption is only true if the case is viable and reasonable. In addition, microgrids are very competitive in the electricity market, especially for consumers of renewable energy sources. From this phenomenon, the price is likely to increase as well, according to Bloomberg New Energy (Climatescope, 2018a) In the figure on the right, for consumers of higher energy, the extension of the energy is less cost because the new infrastructure will be the best solution for the use, which results that the microgrid does not have an effect on energy demand. Second, solar home systems become cheaper and more cost-effective technology for the rural consumers of the average household.

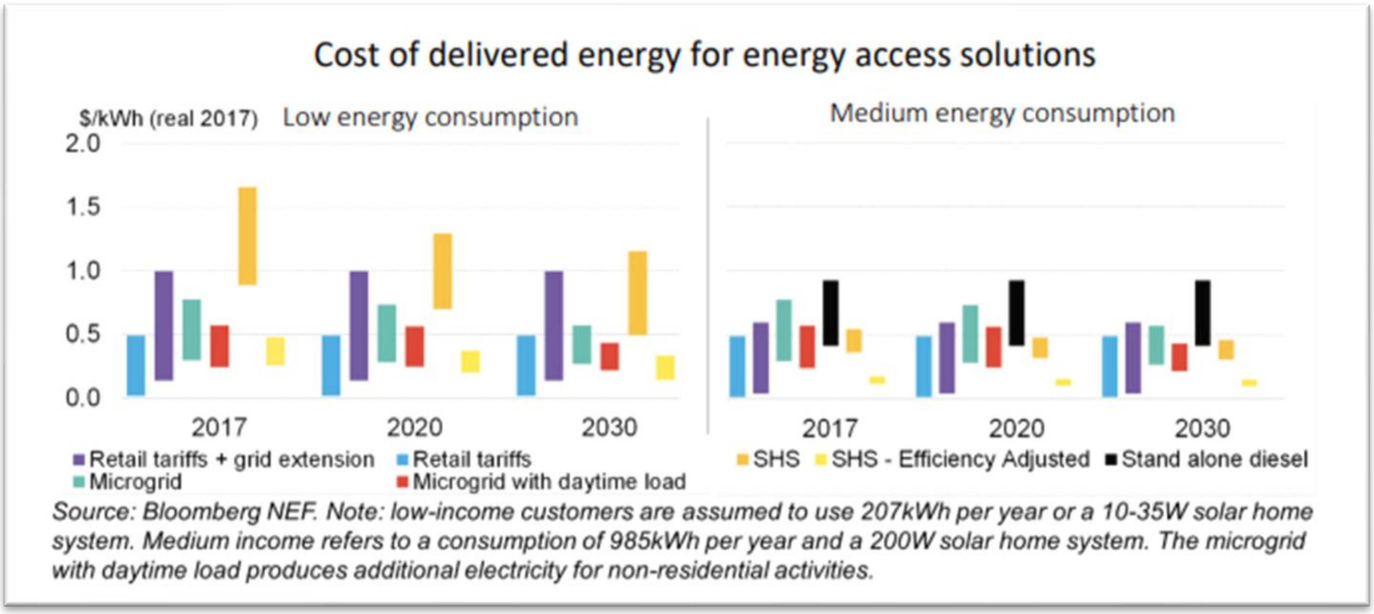


Figure 4:Cost of delivered energy for low energy consumers (left) and medium energy consumers (right) – Source: Bloomberg New Energy Finance.

Mini-grids and solar home systems are proposed solutions to lower the price of electricity by 2030. Therefore, this requires improved business and technological development to ensure their viability. The proposal was also imposed for new information and communication technologies, the market system for energy trading or digitization in the energy access sector.

In 1970, the use of digital technology developed in the energy sector for its improvement and adoption (Sabino, 2018). In addition, this technology is evolving more and more in developed countries. To achieve the level of access to energy in developing countries, particularly in sub-Saharan Africa, the application of this new technique with investor projectors is an effective and viable solution.

II.1.4 *Benefits* of block *chain* technology in Africa

- **Easy access to markets**:

The existence of the market facilitates transactions between producers and consumers. It can solve the problem on the third party which profits a lot of profit. That is to say that the two even parts can be directly communicated by eliminating the lighter intermediates of the chain. In addition, it requires a lower price on the side of the consumer and increases the revenue of the prosumers (Alstone, P and al, 2015).

- **The business environment has greatly improved**:

In the Continent of Africa, smart contacts facilitate the best small business credit using a blockchain system. Thus, the large companies receive this financing which supports the economic stability of the countries (Alstone, P and al, 2015).

- **Blockchain facilitates cross-border transactions**:

The most recent difficulty in different countries, especially in Africa, is the presence of different transaction currencies. In addition, the variation of these currencies is another barrier especially in its attempt to deal one after another. The involvement of the blockchain architecture allows the user to use crypto-currencies as a means of payment. The advantage is to make the speed of the transaction faster in the market (Alstone, P and al, 2015).

- **Low costs of money transfers**:

Another benefit after the introduction of blockchain technology is to eliminate banks as an intermediary and to rebuild reliability and security with the use of bitcoin. The transaction can flow quickly and the processing is done right away not like in the third-party process (Alstone, P and al, 2015).

- **Confidentiality**:

Data privacy is ensured by using unique digital imprints which allows users to secure their personal data. Therefore, data stored by users improves security through cryptography (Alstone, P and al, 2015).

- **Job creation**:

Bitcoin as a currency used in this technology is open to all businesses and industries. This leads to a business investment and creates jobs for all people in Africa (Alstone, P and al, 2015).

This scenario results the development of public and private enterprise and economic growth.

II.1.5 *Challenges of implementation of block chain solutions in Africa*

- **Insufficient infrastructure**:

One of the major problems in Africa is the inadequacy of infrastructure, every manages does not have access to the internet. In addition, the problem of electricity is also a big factor which blocks all the innovations like implementation of this computer technology. So, everyone who does not have a computer or smart phone cannot connect to it for the blockchain network (Davide Mazzoni, Fondazione Eni Enrico Matte, 2018).

- **Technological incompetence**:

One of the challenges in Africa too is the technological incompetence resolved over time, more precisely the speed of transaction is very slow and the security and protection of data are still weak (Davide Mazzoni, Fondazione Eni Enrico Matte, 2018).

- **Government policies and regulations**:

Government policies in Africa still focus on the use of traditional technology, this implies that all populations have not yet implemented their traditional methods. Another challenge is the restructuring of the policy which favors the use of new technologies by stopping traditional technologies (Davide Mazzoni, Fondazione Eni Enrico Matte, 2018).

- **Skills**:

Competence through software developers and competence at the user level that we are talking about here. On the one hand, in Africa there are a lot of intelligent people, especially in the IT field, but they want to invest in developing countries. The real problem is lack of these skilled and competent people, which leads to the shortage of software in the market. On the other hand, many people in Africa have poor quality of education, therefore it is difficult for them to use this new infrastructure. The challenge is to create training in order to be able to handle this new concept through limited funding especially in rural Africa (Davide Mazzoni, Fondazione Eni Enrico Matte, 2018).

- **Fear of crimes:**

Here in Africa, the fear of the branching of money, the fear of the aspect of tax evasion with the introduction of cryptocurrencies like bitcoin are still barriers. Developers should therefore be urged to be more vigilant on issues such as the development of appropriate privacy tools.

This section of the digitalization for Energy Access in Sub-Saharan Africa presents all the access to electricity, all the advantages, the challenges at the level of Blockchain technology. In another chapter, we will explain the Socio-Economic and technological developments in Africa (Davide Mazzoni, Fondazione Eni Enrico Matte, 2018).

II.2 Socio-economic and technological developments

After looking at the situation of Digitalization for Energy Access in Sub-Saharan Africa which presents the status of energy access in Africa and also the benefits and challenges on the implementation of this new technology, the next chapter presents the technological and socio-economic aspects developments that are developing outside the electricity market: the sharing economy and the blockchain technology. This helps to evaluate and analyze the functioning of a blockchain model in order to meet the challenges of the electricity market.

II.2.1 *Sharing economy*

When we speak of the economy, it denotes the creation of added value in order to have a profit, then the sharing economy is a socio-economic concept relating to the general way "the organized sharing of resources by individuals using a platform "; as Greenhouse (2016) describes it:

It's a hip and fast-growing sector of the economy filled with corporate headlines: Uber, Lyft, Airbnb, Task Rabbit. There are people who do not know exactly the term "sharing economy" because sharing is virtual but not exactly real. Some authors have called the "on-demand economy", "the peer-to-peer, crowd-based economy. economy "," odd-job economy "or" collaborative economy "(Greenhouse, 2016).

According to Greenhouse (2016), here are the three concepts of the sharing economy. On the one hand, it is described as a separate part of the economy, but a variety of businesses are said to be part of it. The brightest example of the company that exemplifies the “sharing economy” are the companies Uber and Blablacar. They offer very different activities and operations to the customer to their respective usage pattern. Uber is a company applicable to the mobility sectors of the sharing economy with a turnover of over $ 6.5 billion in 2016 (Reuters, 2017). This company is supplied with a smartphone application where passengers can propose a trip, the drivers are independent of the company but they are paid for each trip. Whereas Blablacar is a platform connects with drivers, who want to drive from one place to another anyway, with potential co-drivers (Botsman & Rogers, 2010). Therefore, the drivers share their route and afterwards the passengers can be contacted if they are interested. The racers pay the drivers a fee for gasoline and for the running costs of the car. So, in summary, the two companies apply the concept of the sharing economy using very different operational and business models. With Uber, runners order and pay for their trip what they want as a very evolving service (LaPlante in Serre, 2016), but with Blablacar, passengers actually share their trip with the drivers, and if they both went in the same direction or destination, the service is concluded.

On the other hand, the term "sharing economy" is different from the underlying market (s) of the platform. This means that the main reason is that the term sharing economy is used for a heterogeneous group of platforms, as described above. Business and operating models differ considerably, as do their impacts on their user base and society at large, giving rise to the discussion of what exactly the sharing economy entails. Some researcher has mentioned that the term sharing is appropriate if consumers pay for a service or a product (Greenhouse, 2016) and advocate for a different terminology, to example the term crowd capitalism as "consumers get services by connecting to a host of suppliers via a platform”.

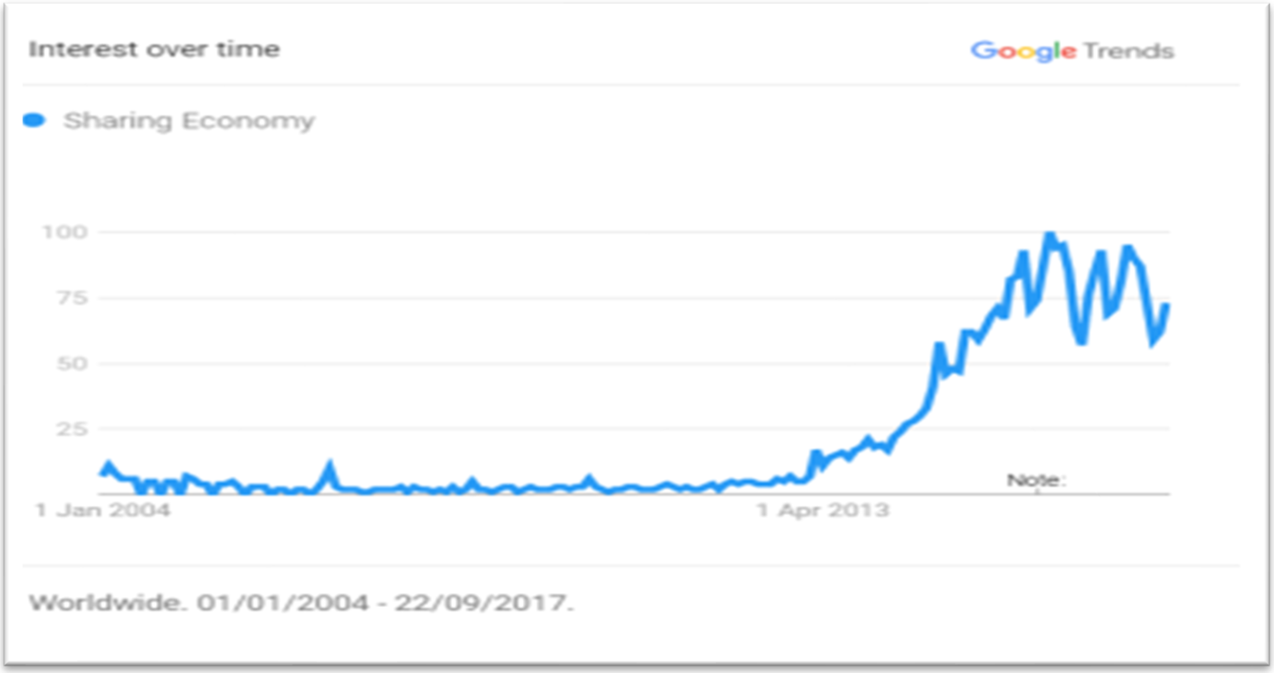


Figure 5:Interest over time in Sharing Economy (Google Trends, 2017).

Third, in recent years, the sharing economy has been driving a rapidly growing market as shown in the figure (5) below. The graphic line (ordinate axis) shows the research interest in relation to the highest point for the given period (01/01 / 2014-22 / 09/2017). In the abscise axes, the maximum value is 100 which indicates the greatest popularity for the term on a day off. The figure shows that from the year January 2004 to 2013 the term is less popular, while from 2013 the term is highly evolved for their popularity.

The advantage of online information sharing uses is evolved by the spread of digital technologies and the internet. According to various authors, such as Codagnone and Martens (2016), "citizens have found ways to organize the sharing of resources for millennia". On the other hand, the prohibition of the scaling of such forms of organization is caused by the increase in the cost of information. However, information costs are falling, with the evolution of new technologies, in addition to internet activities and online sharing, have been growing rapidly. (Codagnone & Martens, 2016).

We can say then that the sharing economy is surely following the socio-economic concept, on the one hand on the social side, the initiative of consumers who offer a service to other consumers or the intention to become a producer to make an exchange; on the economic side, we can create added value, make an exchange and create a meeting between demand and supply via the platform.

Here are the three influences of the sharing economy on the electricity market:

- We can create an alternative economic model by collaborating with the sharing economy (Lombardi & Schwabe, 2017; Plewnia & Guenther, 2017). At the operational analysis level, the sharing economy helps the investor to finance model's collaborative and innovative salespeople. At the conceptual analysis level, this facilitates a transfer of these models to the electricity market.
- The behavior of customers become less active by reclaiming other service provided by other consumers (Del Rowe, 2016, p. 24). In addition, people become closer by sharing the assets they have owned with other consumers (Rousselet, 2014, p. 25). This verifies that the model created on the sharing economy built into the electricity market makes the end consumers accepted because the collaborative services are already done.
- The evolution of the sharing economy assists the evolution of the collaborative market with the acceptance of service providers on the market. Valdman specified that the determining factors of the development of the market are sociology not physics (Valdman, 2016). Therefore, it should be noted that the existence of experience allows to freely impose collaborative business models and to over-settle.

II.2.2 *The blockchain and distributed ledger technologies*

The blockchain is a very innovative technology and its application is increasing more and more in all the various sectors. This section tries to give the introduction to the blockchain technology first of all the principle, after the development of the blockchain and finally its potential application.

- **Functional principles**

Blockchain technology is operated on a computerized platform which has a form of distributed database. All users on the platform are named participants, and who can share the database. Therefore, the participant is not allowed to access the central server of the distributed databases. In addition, users can perform a per-to-per transaction such as online payment. With this, the transfer is carried out directly between two stakeholders without an intermediary or central authority such as the bank. To do this, participants can check the status of the transaction through the consensus mechanism (Deloitte,2017).

Figure (6) shows the conduct of the examination and verification of all payment transactions via the bank against a P2P network.

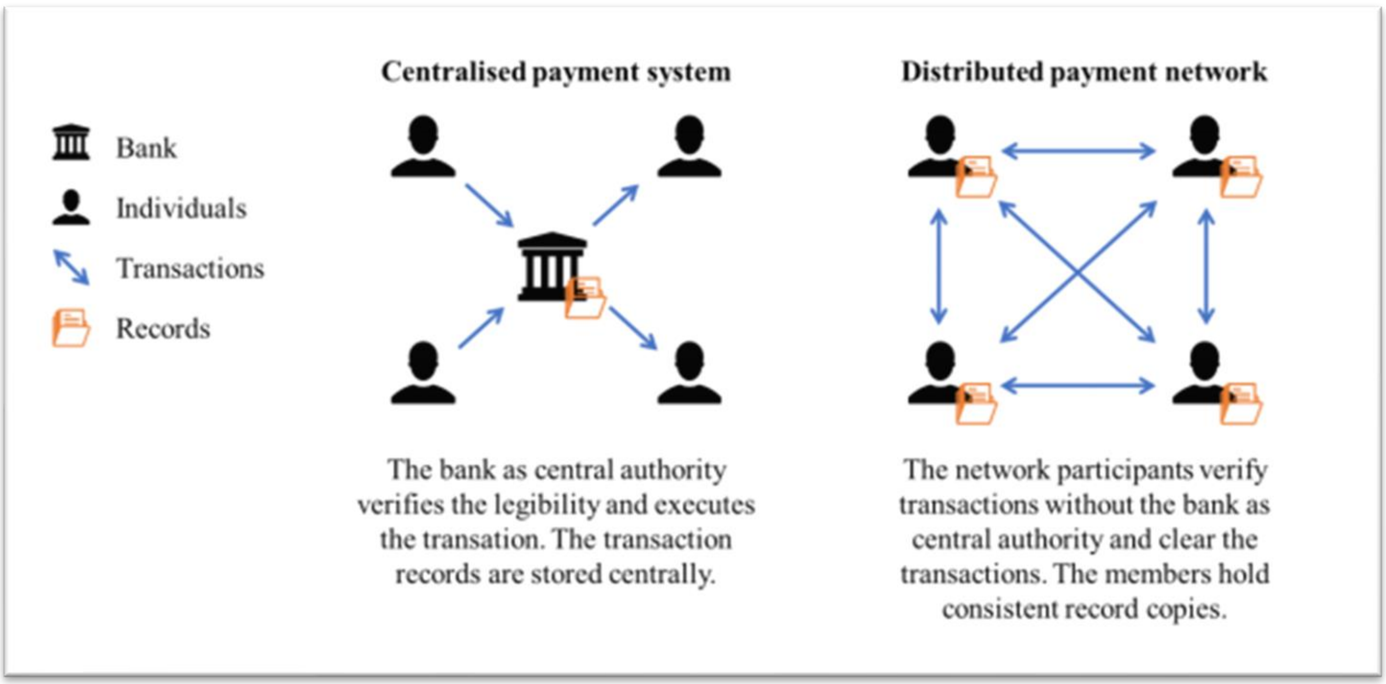


Figure 6:Centralized vs. distributed payment transactions.

Here there are two payment systems, one is the centralized payment system and the other is the P2P technology system distributed as a payment network. Opposite, it is the bank alone which holds all the transaction registration information carried out for example the transfer of money to another account (which appears in the figure 6 on the left). But with the advent of P2P trading as a means of payment, all users have access to the information of the transaction registration list but also, they are all connected to each other through the platform. In addition, there is no more information asymmetry because the P2P system directly eliminates the intermediary who holds the record. From this blockchain, we can also call distributed ledger technology, as the transaction information in the ledger is now distributed and replicated over the network (Deloitte, 2017).

So, we found that the blockchains allow to eliminate the intermediaries in the transaction by creating the ledger replicated and distributed between the two parties concerning the transaction of the blockchain. The following section presents the transaction process, identifying the main distinctions and finally the characteristics of the blockchain compared to other databases. This serves as the basis for the use cases where blockchain could be applied or the solutions it could enable.

- **The transaction procedure**

The users are probably connected to a blockchain network using the computers as a system link device connected to the network. These serve as so-called nodes in the network and each node can initiate transactions. The process of validating and recording transactions is best illustrated by a foreign exchange transaction (TenneT, 2017)

Here is a simulation example to better explain the transaction procedure in the new P2P technology system:

Phase 1

- **A network participant, H, wishes to initiate a transaction of 50 currency units (CU) for another participant, M.**

Phase 2

- **The expected transaction record contains H's node ID, transaction question, and M's node ID. Transaction registration forms a so-called "block".**

Phase 3

- **Next, the block is broadcast to all nodes within the network to let them know of the transaction request by H.**

Phase 4

- **The remaining network now checks, by means of a pre-agreed-upon consensus mechanism, whether H has sufficient funds in her online wallet to execute the transaction. If she has a minimum of 50 CUs, the network approves and validates the transaction.**

Phase 5

- **To make the transaction indelible by network participants, the transaction record is registered in the list of all past records. In a figurative sense, the block is added to the chain of other blocks. This then forms the blockchain.**

Phase 6

- **Lastly, the 50 CUs are transferred from H to M. Their CU balance is updated in their online wallets**

According to these different processes, we have scored three very essential points on blockchain technology. First, the consensus mechanism for the validation of exchanges between the two parties offering and requesting. This is to be done in order to completely suppress the power of the internal as well as the central authorities. Second, the blocks are adopted to have transparency between the participants. This is formed on the mechanism of the large book shared on the platform; in this case, we can make a recording or copy of the transaction. Thirdly, keeping the transaction is not enough to have a sure transaction, but if the participants want to modify some information that is already saved, both parties must all agree to the modification. This means that it is impossible for a single node to have to bring a change on the information, it is necessary that all the users are in agreement by following the mechanism of consensus. In short, blockchain technology ensures the immutability and validation of information as explained above (Castor, A, 2017).

- **Behind the blockchain**

What we already know that all participants have the right to access and monitor all transactions on the platform. Therefore, the data between the two users doing the transaction is private and accessible themselves as explained below. There is what is called "Cryptographic Hash", this is a computerized method of transforming input data (such as transaction and node identification) into a unique combination of numbers and letters (" digital fingerprint '). On the more technical side, all input values are transformed into letters and numbers with a length of 256 bits. For example, the word "good" with a small "g" (Movable Type, n.d.), i.e., the hash value is unidirectional, the input value is different from the hash value. In addition, if one intends to change "G" instead of "g" in the input value, the hash value is modified in an unpredictable way by the hash function (Drescher, 2017). The advantage of the operation of the "Hash" system, on the one hand if the users wanted to make a modification on the transaction data, the hash function also changes and thus declares the money; on the other hand, the hash value stored and visible on the blockchain does not reveal the transferred "content". So, it is impossible to change the contents in this system.

Then there is what we call "mining" which processes transaction data in the blockchain. The process is for the miner to approve an editable input field (the so-called nonce) in the hash function, a timestamp, a reference to the last block in the chain. In addition, the hash output presented above must follow some criteria and conditions in the blockchain and be granted and accessible to all users. (Cameron-Huff. A, 2017).

While registering in the network platforms, each user will receive two different keys, one is the private key and the other is a public key such as the bank account number. The private key is to sign and authorize transactions such as the password or manual signature. In addition, it is used to carry out the transfer of property. But the public keys are identified in order to do (Drescher, 2017).

- **Validation methods**

What we have already seen above, the transaction validation process must go through several stages. Now, there are two types of consensus protocols: one is Proof of Work (PoW) and the other is Proof of Stake (PoS).

PoW is the most commonly used validation method and relies on the mining process (PwC, 2016, p. 7). In solving a puzzle, there is the problem that needs to be solved and it has a job to solve that problem, while the solution is called a PoW. The process in the operation of the Blockchain system is called mining, this means that the PoW or mining is intended to add all new blocks to the chain. On the other hand, if the users wish to modify in the chain, they will have to redo all because the mining does not accept the existing blocks. Therefore, modifying nodes do the job faster than at least 51% of other mining nodes together in order to validate its modification; this is called the 51% attack. The attack would require more computing power than the other combined mining nodes (Follow My Vote, n.d.).

The other protocol is called "PoS", its role is to fill the gaps producing PoW. She does not work but monitors participants in the blockchain network. For example, it integrates when the nodes have a higher currency balance, the more the balance is increased, the more power the node has to build a block. So, this is posed for the big shareholders to protect against the attacks, on the other hand it allows to create blocks without friction and safe. As there is a 51% attack, the node produces 51% within the network. In addition, he can acquire such a stake is expensive for the attacker, as prices rise with higher demand (in the case of currencies) (Follow My Vote, n.d.). (Castor, 2017).

- **Accessibility options**

There are two types of blockchain, private blockchain and public blockchain (Garzik, 2015, p. 11). Public is allowed for all people, that is, all people are allowed to join on the platform and there is no monitoring or control or extra margin act. In addition, the blockchain system controls who has access and who does not (Gramoli, 2016, p. 3). While the private blockchain is limited in accessibility and very tightly controlled every node that performs the transaction. What then is the advantage of using these two types of blockchain? on the one hand, for the public blockchain, centralization minimizes the transaction costs carried out by users because the verification of a transaction is reduced. This process is then beneficial and more efficient for operators, but providers have the power to charge fees for the service provided and to control accessibility (PwC, 2016, p. 12). On the other hand, the private blockchain is advantageous, first of all, they can follow the process of invoicing the service fee, then it can benefit from the automation of their process. This type is very interesting for the company especially for the bank because it uses a very structuring economic model and to protect (Cohn, A., West, T., & Parker. C, 2017).

- **Blockchain development and use cases**

Blockchain is a technology that is evolving faster like the digital payment system. In 2008, Satoshi Nakamoto invented the cryptocurrency which was the initial movement of bitcoin after the introduction of the currency called Blockchain 1.0. Develop on Blockchain 1.0. The role of this type is to deal with the decentralization of payments and currency between users. Blockchain 2.0. is developed for the same purpose as the 1.0 blockchain. but they can benefit from decentralized infrastructures within the markets (PwC, 2016). Confirmed by Swan (2015), "the key idea is that the decentralized transaction blockchain ledger functionality could be used to record, confirm and transfer all terms of contracts and ownership". (Swan. M, 2015). Possible use cases go beyond cryptocurrency and include a wider range of application possibilities. The following provides an overview of the most promising use cases for blockchain technology.

- **Smart contract**

The smart contract is imposed on the process of the operation of the blockchain in order to encode all the nodes on the platform. It is autonomous for the decision on the transaction and decentralizes the transaction between the nodes (Swan, 2015). It uses the if-then contain to validate the transaction process, (for example the automatic sending of an invoice at the end of each month) while respecting the Blockchain condition and the acceptance between the nodes concerned. Blockchain also uses smart contract regulation which can verify whether the terms have been followed by users (Drescher, 2017). Consequently, the contracts placed on the blockchain have for a purpose, on the one hand to eliminate the intermediary to monitor the contracts, on the other hand, to place automatic settlements between the parties concerned according to the condition of the blockchain. The combination of the several conditions on the Blochian requires the proper functioning of a smart contract, such that it can automate the sale of a security if a certain price target is reached and directly settle the transaction in cryptocurrency. So blockchain technology is being invented to rectify the gaps in bitcoin through the smart contract.

- **Ownership documents**

The different modes of creation on the blockchain are the registers of inventory and of tangible and intangible assets. Tokenization is the set of registration processes for all these assets (Cameron-Huff, 2017). Is this principle one of the advantages of using blockchain technology, its ownership registration can be registered in the technology. In addition, once the recording is made, its modification is impossible because other users of the network would detect it (Drescher, 2017). Therefore, the modification does not can only be done using the private key of the current owner.

This means, on the one hand, it simplifies shared ownership of physical assets. It is possible to physically divide a few assets, for example a 1kg gold bar can divide into two 0.5 kg gold bars, but it is difficult for in the case where there are several assets in the company, for example an airplane or a production machine. In addition to another additional benefit to the introduction of shared ownership on a blockchain if the assets are not new, i.e., consider as a corporate shareholder. In addition, it allows to combine ownership records with blockchain-based smart contracts. For example, a car condominium can be managed in such a way that the use of the car is continuously tracked and transactions are settled directly and automatically between car users and owners (EY, 2017). On the other hand, it facilitates the transfer of ownership. The intermediaries are then verified if the seller of a good was really its real owner, and if it is only true, the transaction is done without paper trace and with the possibility of instant settlement (for example using a cryptocurrency).

- **Distributed transaction records**

This feature of blockchain works on the use case of distributed storage of all transaction records. Specifically, in another market, it is impossible to see an offer that was transparent about their transaction information without adding additional fees. These transaction records are then can be used to improve the flow of goods. For example, if a buyer wanted to purchase a product, they have the right to verify their original source and all information regarding the product with a condition of paying excess fees. In addition, a producer has the right to automate his invoicing process using records of transactions with his customers (Deloitte, 2017a).

- **Limitations of the blockchain**

Although there is a lot more to blockchain, there are three cases that could hinder or slow down widespread use.

Firstly, the flow of blockchains is more limited compared to other technology such as VISA which is capable of processing up to 47,000 transactions per second (Beck, Czepluch, Lollike and Malone, 2016), Bitcoin capable of processing seven transactions per second. This limit is due to the size limit of each processed block. They fear that with increasing block size miners with limited bandwidth will be at a disadvantage.

Secondly, the more the blockchain develops, the more the decentralized approach of the blockchain becomes its limit. As we already know that the transaction is between each node, and the inter-node traffic increases in logarithmic form with each node added which results in an increase in latency as more nodes are added (Kasireddy, 2017). Consequently, the latency of the processing limits the opportunities of the blockchain and the development of this technology becomes sluggish (Swan, 2015; Beck, Czepluch, Lollike and Malone, 2016).

Fourth, blockchain technology is very resource and energy intensive (Czepluch, Lollike and al, 2016). The transaction cost, i.e., energy-intensive extraction has been estimated between 1.4 and 2.9 USD (Croman et al., 2016). While other blockchains like Ethereum consume less energy, their energy consumption is over 1000 times higher and the VISA Network uses 20,000 times more energy per transaction (Brosens, 2017).

II.3 Current scenario in the energy market

In general, market trading has evolved with the development of computers and the innovation of the internet. People prefer to use an application on the smart phone or on the networks to make things easier. However, the evolution of P2P energy exchange does not allow consumers to meet their needs in the wholesale market (Cali U and Fifield A, 2019).

Here are the causes of its barriers:

- P2P energy exchange is carried out on a centralized structure on the Market trading platform. The increase in pairs such as prosumers risks having a failure of this system and can have a glaring consequence at the level of the consumer.
- Prosumers are prohibited in the wholesale market and customers are not allowed on the ability to negotiate on price. The prices of electricity that are set by the prosumers are fixed and that is the reason for this barrier.
- The net-metering approach does not allow consumers to sell energy at the price they want and only allows a fixed reward for the energy sold.
- In the current situation, small consumers are not compatible on the independent system (ISO). The ISO operation consists of collecting on a large scale all the offers coming from the participants and selling them from the market liquidation.
- This concept tries to directly eliminate small consumers and that gives the benefit of selected consumers.
- Energy resold by consumers is not paid for in a stable manner.

This is the reason for creating a commercial business model for the scope of the market.

II.3.1 *Electricity business models*

After the birth of a digitalization project on the distribution of energy on the trading market, several consumers are privileged and give a lot of advantage on the economic sectors in addition. In addition, the liberalization of electricity is a source of competition which is still an asset because unit prices have fallen.

The electricity trading model is divided into two parts, one is centralized like the energy pool on a day-ahead market where the uniform price auction is intended to meet the price of the market, the other it is a decentralized market where the pairs are autonomous at its discretion in the form of an electricity exchange contract. But at the moment there are several types of electric market model distributed which we will discuss below.

II.3.2 *Formation of a coalition for exchanges on the electricity market*

A virtual power plant energy management system (VPP) or micro-grid aggregator is one form of centralized business model coalition. It combines all the energy resources that are supplied from electricity such as energy storage systems, combined production of electricity and heat and solar and wind power. The information and communications technology in this system allows the coalition to market electricity through an auction process.

The VPP model combines all the offers of the other VPPs, the technical capacity and the energy distributed to materialize a coalition offer. The minimum bid made by the VPP director is the highest minimum bid presented by each coalition member. Once a VPP has won the auction, the contract is signed by the auction manager (Jafari M and Foroud AA, 2020).

II.3.3 *Power purchase contract*

The electricity purchase contract is a contract directly between the suppliers and the electricity loaders such as VPPs. There are two types of power purchase contract to provide a condition in the form of duration, price, amount in MW and hour of supply. One is the futures contract where the two parties involved negotiate in the exchange and are not bound to the agreement but they can likewise trade until the deadline for delivery. The other is the forward contract where the charges and suppliers negotiate in the exchange like the VPP with a well-defined agreement (El Khatib S and Galiana FD, 2007).

II.3.4 *Auctions in the form of a sealed auction at a uniform price*

This method involves collecting all sealed bids from electricity buyers and the electricity supplier for each 5- or 15-minute interval period. The auction is the intermediary between these two parties by sealing the duration, the time of delivery, the amount of electricity and the minimum price sought.

Figure (7) explains the evolution of the demand curve and the cumulative supply. The participants sort the supply from low prices on the supply curve while on the overstated demand side, the anchor person sorts from high to low.

Then the figure (8) shows the intersection of two curves which call: the market equilibrium price (MCP). This point of intersection is the equilibrium point of the market where supply is equal to demand. At this point, the auction manager removes all bids above MCP and all demand-side bids are cleared that are equal to or greater than the MCP. This system of auction is also called uniform price because all the sellers who bid for a price lower than the market clearing price will be paid an amount, which is nothing other than MCP (Shah D and Chatterjee S, 2020).

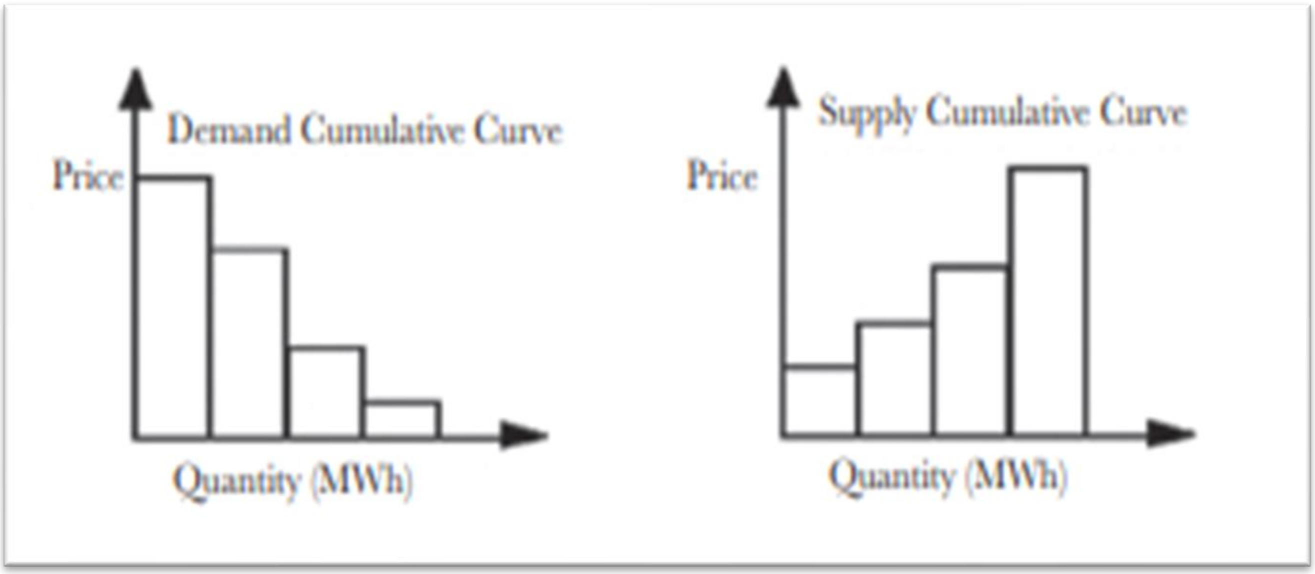


Figure 7:Demand and supply cumulative curve.

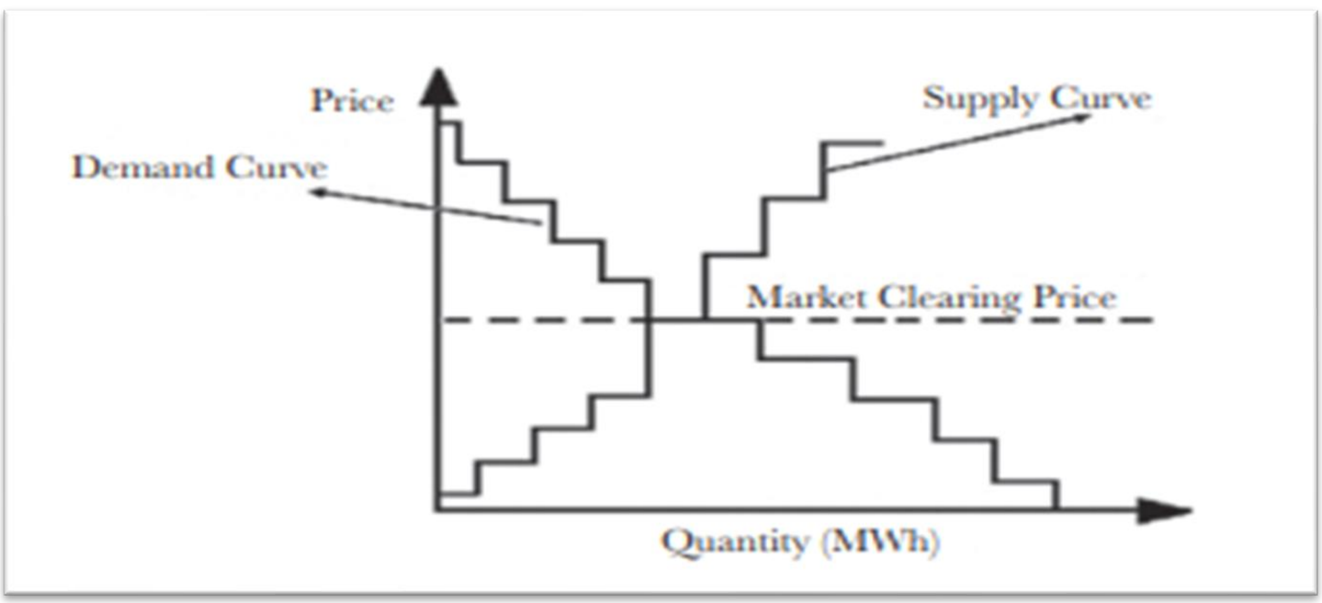


Figure 8:: Uniform-price sealed-bid auction.

II.3.5 *Basic requirements for P2P-based configuration energy markets*

Here are the seven component requirements for the establishment of a P2P energy market (Mengelkamp E and al, 2018):

1. **Market mechanism**:

The establishment of the modus operandi which is to ensure energy auctions on the P2P energy trade. It will be very useful this component there, before the commercialization of operational microgrid energy.

2. **Pricing mechanism**:

This is a component that ensures the profitability of the production of energy, in case of excess, it will have to lower the price, on the contrary, the price must increase.

3. **Energy management exchange system**:

It is a part of the micro-grid energy market that collects real-time demand and supply from its market players and consequently plans for energy auctions.

4. **Regulations**:

This is necessary for planning on the current platform in order to regulate all activities between users. Precisely, he collaborates all negotiations on the P2P micro-grid electricity market.

5. **Information system**:

This technology has for a role of communication between the participants all the information in exact time on the price of energy. It also assures the common benefit of users with regard to the purchase and sale of energy in conjunction with the same dissemination of information received. It is very essential that this technology be put in place for the proper functioning of the exchange.

6. **Establishment of the micro-network**:

The location of the micro-network limits the participants who wanted to exchange energy. There should be prosumers capable of producing a traditional network to trade in a well-segregated transport line set up. with the traditional mesh, which is maintained at the same level of voltage as the main network. This would help local consumers to sell energy not only to their peers, but also to the main network in case of surplus or to buy on the network in case of deficiency.

II.3.6 *Affected companies and investments*

This technology is becoming more popular all over the world. At a minimum, 189 companies are adopted and applied this technology with main company investment of around 466 million USD (IRENA, 2020). The debut of this technology in 2016 until now and the three countries like Germany, the Netherlands and the United States are leaders in this technology. In the table 3 lists all the companies that have invested in blockchain-based energy sector applications.

Table 2:Companies invested in blockchain enabled energy sector applications.

Company Name	**Country**	**Brief Description of Blockchain Application in Energy Sector**
Energy Web Foundation	Switzerland	Launched in year 2017 by Rocky Mountain Institute and well known blockchain developer grid Singularity. This foundation aims at application of blockchain technology in energy sector to design an open market for large number of participants.
Grid Singularity	Germany	It was founded in year 2016. The basic aim of this company is to design a blockchain based decentralized system to

		share the energy data which can be used for load forecasting, demand-supply management etc.
Power Ledger	Australia	Founded by Dr.Jeema Green, this company has developed world first blockchain enabled P2P energy trading platform. Their proprietary software is being used by multiple countries like Thialand, India, Japan and United States.
WePower	Lithuania	Founded by Nikolaj Martyniuk.in year 2018, this company gives a blockchain enabled platform to connect the green energy producers directly with buyers. This is also a fundraising company for renewable energy deployment.
Sun Exchange	South Africa	Founded by Abraham Cambridge, this company uses blockchain platform to connect the people who want to invest money in solar energy. The company pays

		the dividends to investors in proportion to the energy generated.
Solar Coin	USA	This company Started in year 2014 by founder Nick Gogerty. Solar Coin is a cryptocurrency introduced by this organization (a leading company in blockchain) which is active in around 32 countries. One solar coin is rewarded by the organization for per Mega Watt Hour of solar energy produced. Anyone securing a solar coin by convert it into flat currency within these 32 countries or may use it to buy power.
Sonnen	Germany	Founded by Christoph Ostermann Sonnen, in year 2019, this company did a pilot project in collaboration

		with another company Tennet to demonstrate how decentralized energy storage system installed in household can be networked through blockchain technology and used in stabilization of grid.
Nimray Solar	India	Working on designing blockchain based solar energy trading system with the help of mobile Apps.

II.3.7 Blockchain platforms used in the electric power sector

50% of the total of start-ups in electric energy used the Ethereum platform for designing blockchainS-based solutions, followed by fabric Hyperledger, Tendermint, Interbit and other flat Sforms. Likewise, 55% of the total blockchain use cases in the energy sector use PoW consensus algorithms followed by PoA, PoC and others (Andoni M and Robu V,2019).

II.4 Identified gaps of the existing literature

II.4.1 *Blockchain gap according to the different authors*

Internet of Things ecosystem compromising a wide variety of devices, including wearable sensors, smartphones, network devices and laptops, generate massive amounts of data at very high speeds. Users are not always able to handle this influx of data (Jhim Kiel M Verame, 2018).

In addition, the adoption of blockchain has given favor to many agents such as an agent of the energy trade and for the protection of the environment. It ensures all the transparency and confirms the trust between the two stakeholders. A few multi-agents offer a solution to solve the scalability of Blockhain technology but they have not yet arrived at the writing of the unfolding (Qayumi et al, 2015). And also, the energy transaction via the blockchain is not seen, the users then are still unknown and not referenced and that is why Fortino et al suggested a model of reputation of the software agent in which the return is summarized. informing consumers about their services (Fortino et al, 2019).

II.4.2 *Infrastructure gap*

There is a gap of 48 billion dollars per in Africa on the infrastructure according to the IMF, the World Bank and other financiers. In addition, the empirical data is still weak due to the lack of infrastructure and economic growth (World Bank Group, 2017). According to the figure below, the claim is that if the obstacles to the deployment of capital projects can be reduced, it can have a positive impact on the continent.

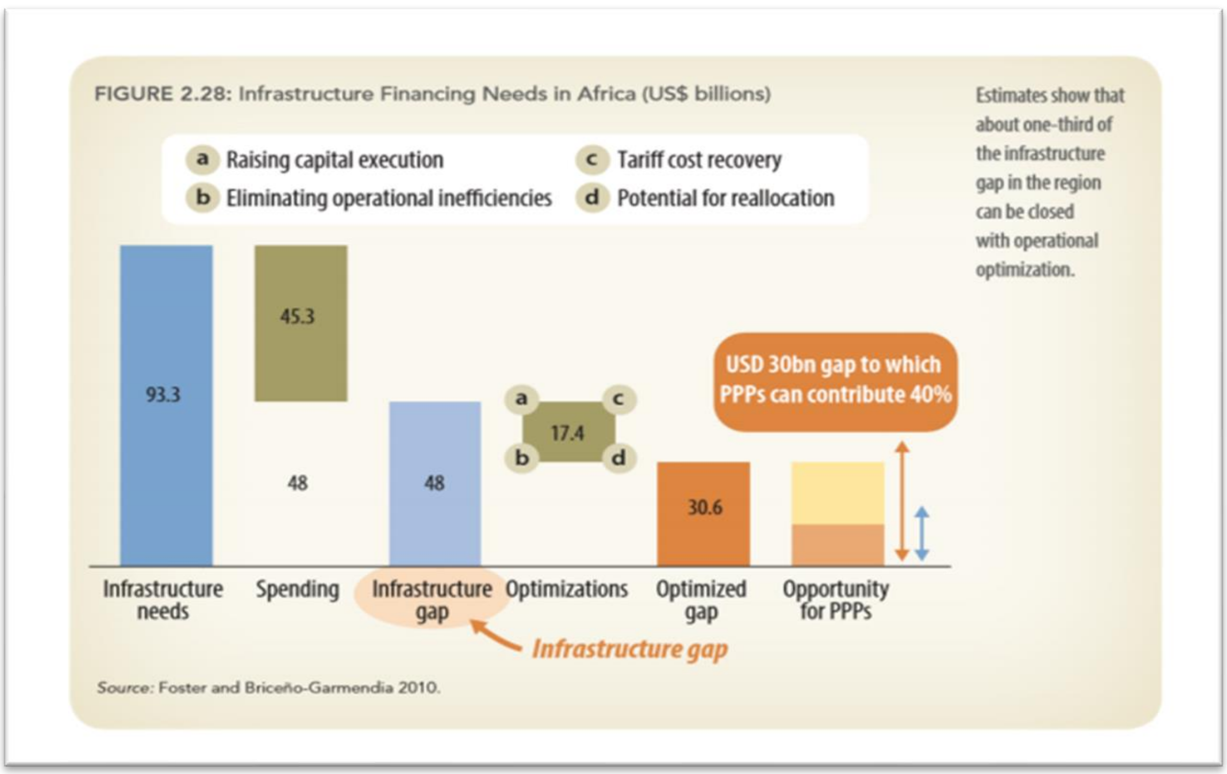


Figure 9:Infrastructure Financing Needs in Africa (US$ billions). Source- Africa's Pulse Spring.

II.4.3 *Access Electricity Gap with Blockchain*

Various studies have been carried out on the political framework for the promotion of digital technology in the mini-grids sector in SSA, the case of blockchain technology. Some of the studies were carried out in areas that do not have access to electricity. Few studies have been adopted in urban areas of Kenya, particularly in non-electrified areas with no possibility of extending the electricity grid. Access to electricity in Kenya is 75% of the population while in other African countries who have only the half. Consequently, this increase is fairly unevenly distributed, especially over the 14 departments supported by the program, well below the national average in terms of electrification rate (Agence Ecofin, 2019).

The proposed research consists of evaluating the potential economic, social and environmental impact of the development of a blockchain-based P2P energy exchange system, evaluating the perception and acceptance of the technology by customers / prosumers and finally to carry out a comparative study of the advantages of the P2P energy exchange based on the blockchain with the two other alternatives: the conventional model of centralized energy system and the conventional mini-grid system without P2P exchange

In addition, this study aims to contribute to the knowledge Socio-economic feasibility study of blockchain-based peer-to-peer energy system in Africa. The study also hopes to design a system that will improve people's long-term access to electricity. Will sustainably improve the lives of the inhabitants of this community.

III. CASE STUDY: ALGERIA OVERVIEW

III.1 Algeria's Energy Background

Globally, electricity production is estimated at 3203 billion kWh. Hydroelectric energy which holds the first source with 96% of renewable sources, after geothermal energy which produces 8,600 MW of power and more than 59 billion kWh of electricity and the third is energy that comes from solar as photovoltaic which produced at a scale of 5.9 billion kWh (Panorama and perspectives of Algerian renewable energies, 2007).

Algeria is one of the African countries favorable to the intensive use of renewable energy sources (RES) such as geothermal energy, wind power, biomass, solar energy, etc. It is located in North Africa between 88 and 128 north longitude and 358 and 388 latitudes, with an area of 2,381,741 km2 and a population of 32.5 million

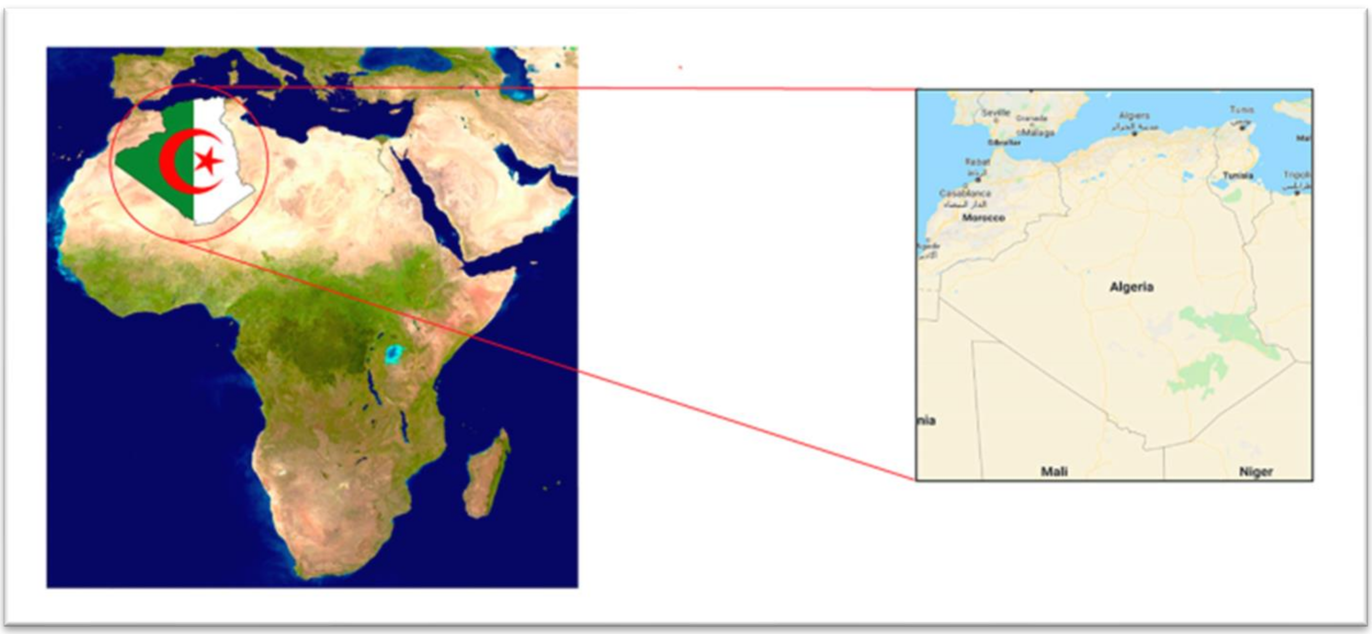


Figure 10:Algeria's location in Africa.

The Sahara Desert occupies 80% of the area to the north, on the coast of the Mediterranean Sea. To the southeast with Niger, to the west with Morocco, Mauritania and the Sahara, to the southwest with Mali, to the east with Tunisia and Libya, and to the southeast with Niger. The climate is transitional between maritime (north) and semi-arid to arid (middle and south). Average annual precipitation ranges from 500 mm (in the north) to 150 mm (in the south). The annual mean temperature is around 12 8C (Himri Y et al, 2008).

Algeria is the 4th economic power in Africa, with a gross domestic product (GDP) of 178.3 billion USD (Organization of the Petroleum Exporting Countries: OPEC, 2020). The economy depends on the production and export of gas and oil. One of the national companies in Algeria named Sonatrach is mainly responsible for the hydrocarbon sector. And also, it is a country richest in fossil energy like fuel which is a member of the Organization of the Petroleum Exporting Countries (OPEC) (World Energy Council, 2020). The oil and gas basins are located in seven such zones:

• The Timimoun, Ahnet and Mouydir basins in the central region;

• The Ghedames and Illizi basins to the east;

• The Reggane and Tindouf basins in the southwest.

The country has the 7th largest oil reserves and the 3rd largest gas reserves in the world.

III.2 Obstacles to the development of renewable energies

The use of renewable energy is still a big barrier because of the many potentials for the use of fossil energy (Overview and perspectives of the Algerian renewable energy, 2007).

- Poor inter-sectoral coordination and communication that does not only slows down the promotion of such projects, but also leads to duplication of efforts and weakens human capital accumulate.
- Slow process in the implementation of the application decrees which takes time and prevents the implementation of essential measures for the promotion of such projects.
- Human capital. Staff continuity is essential and also
- staff turnover prevents long-term accumulation of experience and the process becomes too dependent on individual participation, or lack thereof.
- Lack of knowledge networks. Capacity building seminars on an issue of interest to different stakeholders can only benefit due to lack of dissemination of information.

III.3 Social, Economic and Environmental

The country is able to launch a renewable energy project which aims to improve the development of the country from a social, economic and environmental point of view. Renewable energy aims to reduce unemployment, improve the education sector of agriculture, reduce carbon emissions and have a municipal water supply.

The Renewable Energy Development and Energy Efficiency Program or PEDEEP can create jobs by creating 100,000 jobs each on national production and exploration of renewable energies (Shahan, Z, 2020). According to Inès Magoum, (Ecole Normale Supérieure des Energies Renouvelables to be set up soon), the construction, installation, manufacture, operation and maintenance of the 20-year solar photovoltaic project will create an average of 9.57 jobs / MW. The wind power project will create 0.93 jobs / MW. Therefore, around 3,800 jobs are still available in now.

III.4 Renewable energy policy in Algeria

Since 1999, the Government of Algeria has given priority to the renewable energy sector by applying a specific legislative framework and indicating a financial regime for the development of this sector. The adoption of the law on renewable energies is the means used by the person in charge to achieve the objectives of the development of electricity in the country.

In addition, the Renewable Energy Program adopted by the Algerian government in February 2015. About 22 GW of renewable energy will have been installed by 2030 but 4.5% of renewable energy has been installed in 2020(Algeria Energy situation, 2020).

One can see on the figure.11 the legislative framework and its evolution as well as the details on the law and on the Web site of the ministry of energy and mines.

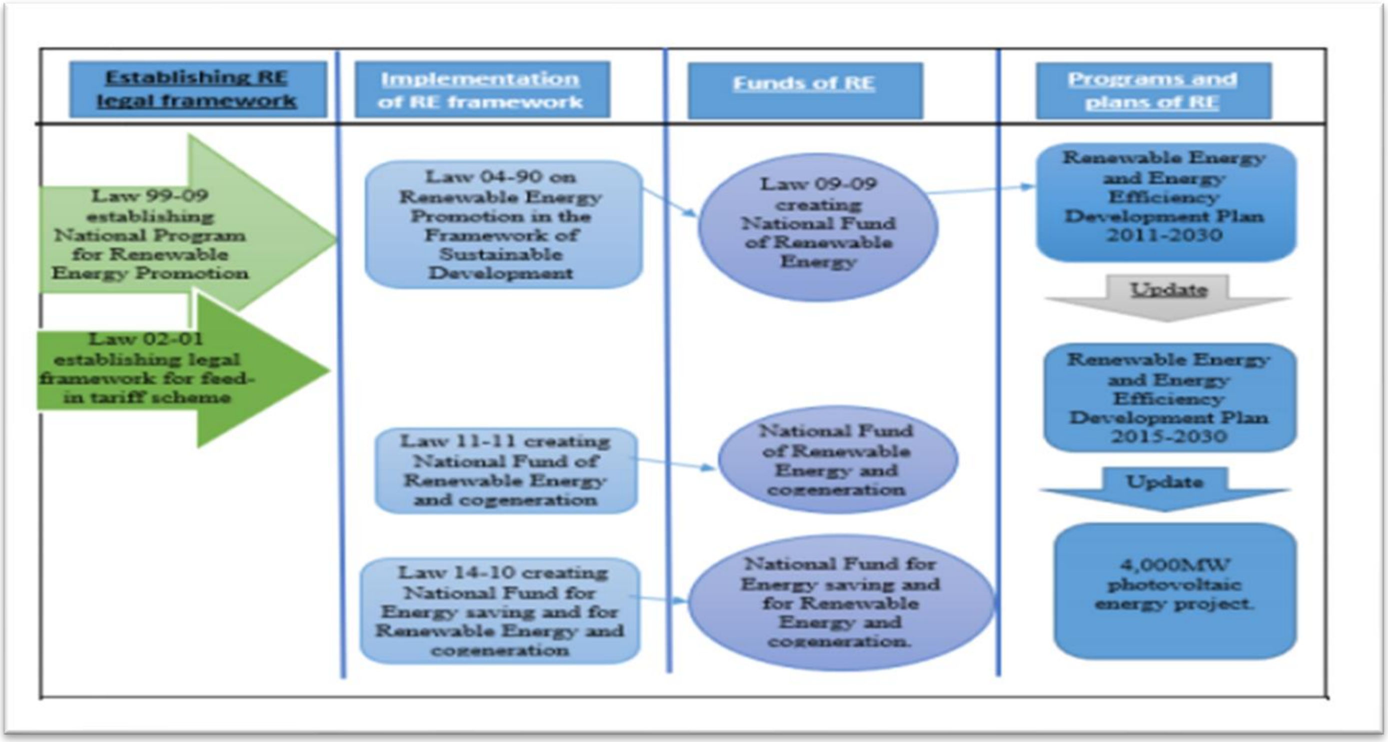


Figure 11:Legal Framework of Renewable Energies in Algeria.

III.5 Electricity access rate and real price in Algeria.

The government of Algeria has adopted an electricity and gas infrastructure policy since independence in 1962 until now in order to improve the quality of life of the population and the economic situation of the country.

III.5.1 *Algerian Electric Network*

The production capacity installed on the electricity network in Algeria is 18,985 MW shared between the national network (17,477 MW), the network of the Sidi-Belabes region (917 MW) and isolated grids (786Mw) (SONELGAZ Group, 2018).

The new generation electrical network or intelligent network technology is imposed in order to reach the maximum sources of energy to households by integrating with communication and information. The goal of a smart grid is to improve the durability and reliability of energy technology. It makes it possible to stabilize the system which has no influence by network failures (B. Buluc et al, 2016). Figure (12): below better the Electricity Network Map of Algerian.

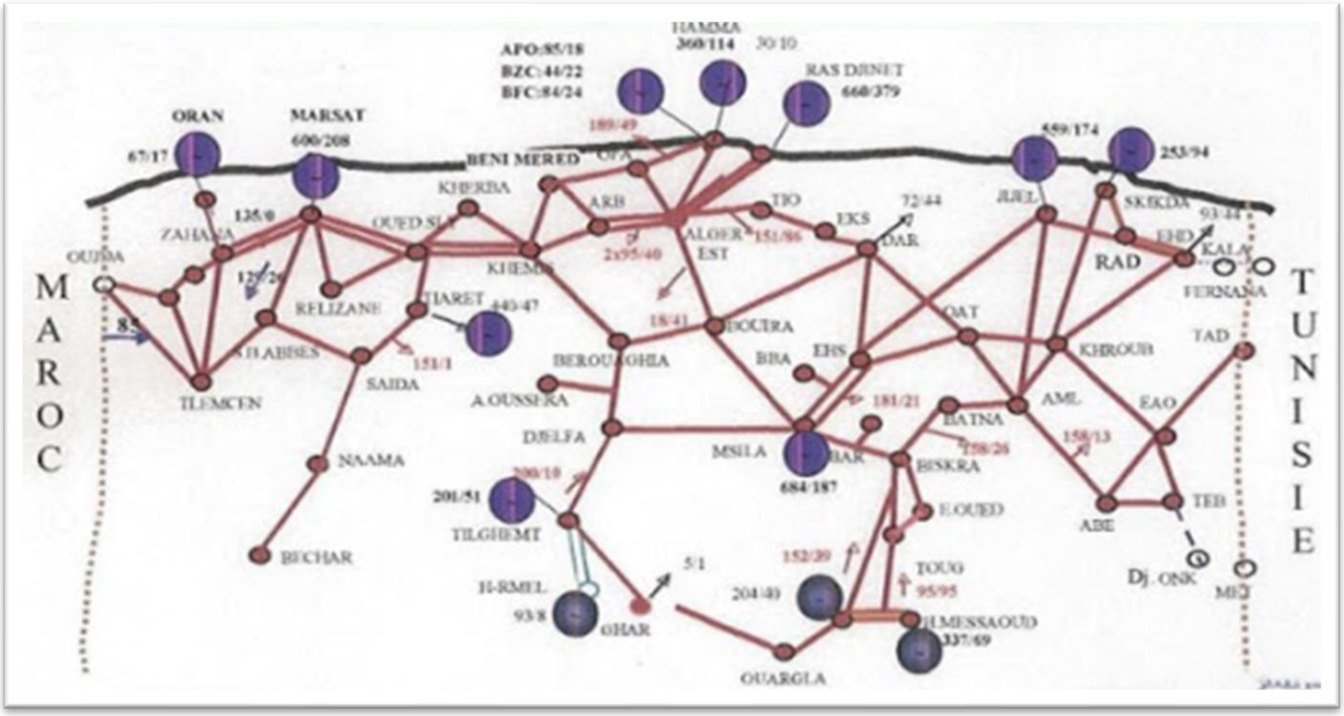


Figure 12:Map of Algeria Electricity Grid- Algeria National Electricity.

As shown in the figure, in the North of the Country and certain regions of the South such as Béchar, Hassi Messaoud, Hassi R'mel, Ghardaïa are covered by the National electric network. There are 40 power plants which are interconnected by high voltage transmission lines (200 kV, 400 kV) (Algeria Electricity grid, 2020).

In addition, from these different potentials in Algeria, the electric network needs this intelligent technology. Here are the advantages from the different characteristics (Abdelkader HARROUZ, 2017):

- Complex network and control structure
- Integration of electricity production at the level of distribution and transmission.
- Development of communication technology • Reduction of losses in transmission and distribution lines.

- Increase in new types of smart devices
- The conventional electricity network is evolving.
- Two-way communication.
- The customer is part of this network
- Control of energy flow
- Dynamic pricing and response to demand

III.5.2 *Rural electrification*

In 2010, according to statistics from Algeria, 260,000 villages still have poor access to general network electricity. The sources of electricity that they are used are diesel generators, but some households use solar energy sources. But now the cost of diesel is getting very high and they also pollute the environment. This is why the Algerian State has set up the project entitled "Solar villages" where photovoltaic solar kits are deployed in all isolated villages with a limited number of houses (Sonelgaz, 2019). The goal of this project is to facilitate access to electricity for all but also improve the way of life with electricity in Algeria and the project is envisaged to cover 34 villages in total (Z. Bouzid et al, 2015). At the same time, there is also a project in collaboration between the government with the Institut Catalàd'Energia (ICAEN), the Renewable Energy Development Center (CDER) and the Tamanrasset region, which was intended for refugees in "Assekrem" in Tamanrasset (A. B. Stambouli, 2011). Consequently, more than 444 solar panels have already been installed since 2012 in order to supply 540 families (Z. Bouzid et al, 2015)

III.5.3 *Real price of electricity in Algeria*

The price of electricity in 2017 according to statistics in Algeria is \$ 0.04 / kW, with a subsidy of \$ 2.3 billion to the price of electricity (Algeria electricity prices, 2019) and 60.7 Twh a unit consumed (IEA, 2019).

Using the relation provided by the international energy agency (2.1):

Subsidy = (Reference price – End-user price) × Units consumed (2.1)

We find:

Reference price = [Subsidy / Units consumed]–+End user price

Therefore:

Reference price= (2.3*10^9 /60.7*10^9)-0.04

Reference price=0.0778 $/kWh

The real price of electricity without subsidy is 0.778 $/kWh which represent 200% of the market price.

III.6 General information about Sidi Bel-Abbès

Located in the west of Algeria, with almost around 300,000 inhabitants, it is the 8th largest city in the country, 80 kilometers from Oran, s the town of Sidi Bel Abbès is at a real crossroads between the major coastal towns of that part of the country. Occupying a strategic position, it is crossed by the main roads in this part of the country. Thus, the intensification of mass transport, a highly energy-consuming sector, remains one of the main sources of air pollution and greenhouse gas emissions in the country. This concern has therefore been integrated into Algerian environmental protection policy.

Table 3:Algeria-Municipality-of-Sidi-Bel-Abbès-Sustainable-Energy-Action.

President of the APC (Assemblée populaire communale)	Mr. Djilali BOUMELIK		
Population	295,000 (2013)	Area	69.74km2
Total consumption	1,777 GWh EF / year (2014)	Energy per capita	6 MWh EF / year / inhabitant

Total GHG emission	681 kteqCO2 / year (2014)	GHG per inhabitant	2.4 teqCO2 / year / inhabitant

III.6.1 Ambitions projects underway at Sidi Bel- *Abbès*.

It is the mobilization of all the actors of the territory, the reduction of consumption and the promotion of renewable energies are Governmental projects for Sidi Bel Abbes. Here are some actions in progress across 3 sectors related to the energy transition:

1. **Raising awareness among citizens:**

the APC has already experimented with an action by organizing an awareness day open to citizens during the implementation of the pilot project on selective sorting. This type of initiatives linked to the popularization of energy issues in the local media could naturally be developed in the SEAP.

2. **Transport:**

The completion of the tramway project will improve the city's urban movement and contribute to the city's modernization. The 17 km route is already completed.

3. **Public lighting:**

Public lighting and public buildings (administrations, mosques, schools) with the integration of renewable energies including solar energy: the renovation of the energy program is intended to be comprehensive. The idea of the city councilors is to modernize the management of electricity to reduce the city's energy bill. The study has already been completed.

III.6.2 *Some examples of action*

<u>Use of LEDs for public lighting</u>: this action is an effort for the responsible in the municipality. He was piloted on a few boulevards in the town. A new residential area was piloted for the installation of lighting new generation audience. The identification of the action was in favor of a new residential district, so that it could be easily valued, but also a district whose promoters undertake to collaborate with the APC on the establishment, monitoring and maintenance of this equipment.

The APC was envisaged to make an extension of this project for the benefit of the inhabitants in the commune with the use of models describing, in the form of synoptic diagrams, the deadlines for carrying out the extension. More precisely, the project was developed with the use of the MS-PROJECT software by the simulation of the PERT network and the GANT diagram.

Development of public lighting powered by photovoltaic panels: the replacement of 750 candelabras was installed by the public company (equivalent to an energy saving of 600 MWh / year and a reduction in CO2 emissions of 334 tones / year). The development of these photovoltaic panels is in charge with APC with their extension in the district of the municipality.

Identification of a pilot district: A district will be selected for the installation of new generation public lighting (rather a disadvantaged district).

Partnership with local company: The agreement between the APC and the company has been clearly formalized the sizing of the project (district offered in concession by the APC) to achieve the goal of 500 more light points powered by photovoltaics.

IV. METHODOLOGY

The application of blockchain in the energy sector is a new, relatively unexplored subject of research (Tapscott D & Tapscott A., 2006). An exploratory methodology is necessary when a research problem has few previous studies, to build new knowledge and familiarity through initial surveys (Streb CK, 2010). This approach is particularly useful for studying the limits within which problems and opportunities may lie and identify relevant factors for further research.

The methodology is a section to meet all the objectives mentioned in the Introduction section. In order to respond Evaluate the potential economic, social and environmental impact of the development of a P2P energy trade based on blockchain, and on the assessment of the perception and acceptance of the technology by customers / prosumers, we tried to adopt an open household survey where the results are discussed below. The dynamic model based on the P2P trading system was created in order to make a better comparison of this new system. In this Methodology

In this research, there are five phases in order to reach the General objective:

1) **Elaborate / documentary analysis: that is to say study of the literature which is related to the subject and to the preparation on the ground.**
2) **Data Collection: This phase develops all field activities and techniques in collecting the required data from the community and Ministry of Electricity offices.**
3) **Data Preparation: After completing the collection steps, process this data into a final product that can be used for further analysis.**
4) **Modeling from the data collected: We will create a representative model of the study area using software (VENSIM).**
5) **Reporting of results: consists of reporting on all research activities and results.**

IV.1 Preparation

The subject of interest in order to better realize the methodology. In addition, it is a phase of preparing field data and all the activities that concern it. A literature review consists of a critical and specific assessment to develop this research and obtain scientific knowledge, i.e., it includes many references. The review of the literature generally focused on the socio-economic and technological developments and the application in the market which will bring us the creation of the dynamic energy system using the application of the VENSIM software to the studies of energy systems. The VENSIM software is used to build models: the tools for building compartments, determining variables and different flows are easy to use. In addition, a simulation tool which is possible to perform several numerical simulations for the same model and to compare the results in graphical form. In addition, it allows you to build models: the tools to build the compartments, determine the variables and the different flows are easy to use. Statistical software such as Microsoft Excel was used for data processing.

IV.2 Research design and data collection

This study is based on a socio-economic survey related to the research topic, in which the cross-sectional research design was used and in which the data of the respondents were collected at different points, where both. An intentional and cross-sectional data collection approach was adopted. Survey and interview were used as a research technique. The survey includes questions on the social, economic plans and on all the information related to the technology of the energy system, the interviews were carried out with some representatives of the person in charge of the electricity in the field of studies. Finally, some data has been collected from online data archives and collected within the ministry.

IV.3 Research Instruments

To obtain information on the study area, a semi-structured questionnaire was developed for each respondent. More specifically, the content of the questionnaire includes on various aspects such as the income of each household, standard of living, renewable energy technologies, access to the national electricity grid, the price of electricity, consumption of electricity. electricity for each household and appliances used for each household in the case of the study. The opinion of the Menages on the energy p2p trading digitalization project was raised in order to have as much information as possible on the study.

IV.4 Data collection techniques

There are two types of data that are collected on the basis of the survey during the field descent. One is primary data, which is collected on the basis of the open and closed questionnaire and the checklist for key informants. The other is secondary data, which was obtained from information published or not in various private or public sources from the examination of the relevant document. Some data has been gathered from important information according to the standards of useful data needs.

IV.5 Data processing and analysis

In this process, the data were analyzed using descriptive statistics, qualitative and quantitative methods. Descriptive statistics such as frequency and percentage were used to analyze the socio-economic and technological characteristics of the respondents.

IV.6 Study limitation

The investigator was making a challenge for collecting data in the area that was not to be known i.e., the researcher was spending a lot of time, resources, COVID-19 and long-distance targeting communities when collecting data.

One of the challenges that the researcher overcame is that the study area is not well known as strange, it is difficult to access the target area. To achieve the goal of the study, it takes two field agents to guide me along the way to get there. Consequently, the researcher incurred additional costs which were not foreseen.

In addition, it was difficult to collect data for some people to open up and give accurate information. In order to meet a challenge, the researcher attempted to hire two more people to help him better perform the data collection.

We already know that we are in a critical period for the health crisis of covid-19, including in Algeria. When collecting data, another challenge that the researcher must face is that of health. Every respondent is afraid to face up to answer the question, and there are people who refuse to avoid contact with the researcher. This is why the researcher must always ask for the consent of the respondents if he is willing to participate in the filling out of the questionnaire and in the interviews; thus, he assured them of the anonymity and confidentiality of their answers.

All of this had a direct consequence on the completion of the data collection phase, thus forcing the researcher to adjust the work plan.

IV.7 System Dynamics Terminology

The dynamic system is used during this project to create a reliable model. The Dynamic System was created by Jay Forrester in 1950, he is one of the pioneers of MIT. He trained as an engineer with experience in return control systems during WWII. Its primary interest is to solve problems on the management and access of the first computers on campus which led MIT to develop an understanding of the dynamics of supply chains and a model-based theory to explain the coup effect. whip. This work was published in HBR and the field of study initiated as Industrial Dynamics (Forrester, 1958). Since that time, the modeling of the dynamic system has developed and become as a field of study in the University. For example, Defra's work has been used system modeling of dynamics in policy making and with the catapult of transport systems on group model building (Yearworth, 2014a, 2014b).

IV.7.1 *Variables*

We have divided 7 groups of variables in this project and these variables are connected for each of them. Each variable will be used to define the causal loops of each system and a stock and flow diagram will be created in Vensim. In the modeling of the dynamic system, there are two types of variables, exogenous and endogenous.

This explains why the exogenous variable is a variable which is independent of the dynamic system, on the other hand the exogenous variables are variables which are linked to one another.

1. Economic growth (GDP)
2. Demand Sector
3. Production sector
4. IPPs Investment
5. Share of Technology
6. Electricity Price
7. Marche per-to-per energy trading

IV.7.2 *Feedback loops*

In the dynamic system model, the main key is structure. That is, the feedback of information and the structure of the system depends on the dynamic behavior. The representation of the model contains structure that leads back to the dynamic complexity that we see in the world.

The notion of the mutual causal feedback loop plays a very important role on the structural mechanism in the modeling of the dynamic system. In this project, there are two forms of feedback: One is negative feedback or balancing feedback, which leads to goal seeking or controlling behavior in a system.

The other is positive feedback, also known as reinforcement feedback, which causes unlimited growth until it is limited by exogenous factors.

From the data collected by interviews for the representatives of the energy sector in electricity and the various information such as the government, the private sectors, the universities and the household, we have identified all the obstacles, challenges and measures which could be raised at the barriers. It is from all the qualitative information that a dynamic system methodology that could help to understand the complex interaction of the energy sector especially electricity in Algeria with the domains on the social economic impact.

IV.7.3 *Modeling*

The first step as a new model parameter is the specific window. It includes the start time, end time, time step, time units in which the corresponding information has been added., By pressing the OK button at the bottom and the mode is well set and ready to start. The diagram below shows the model parameter and its functionality.

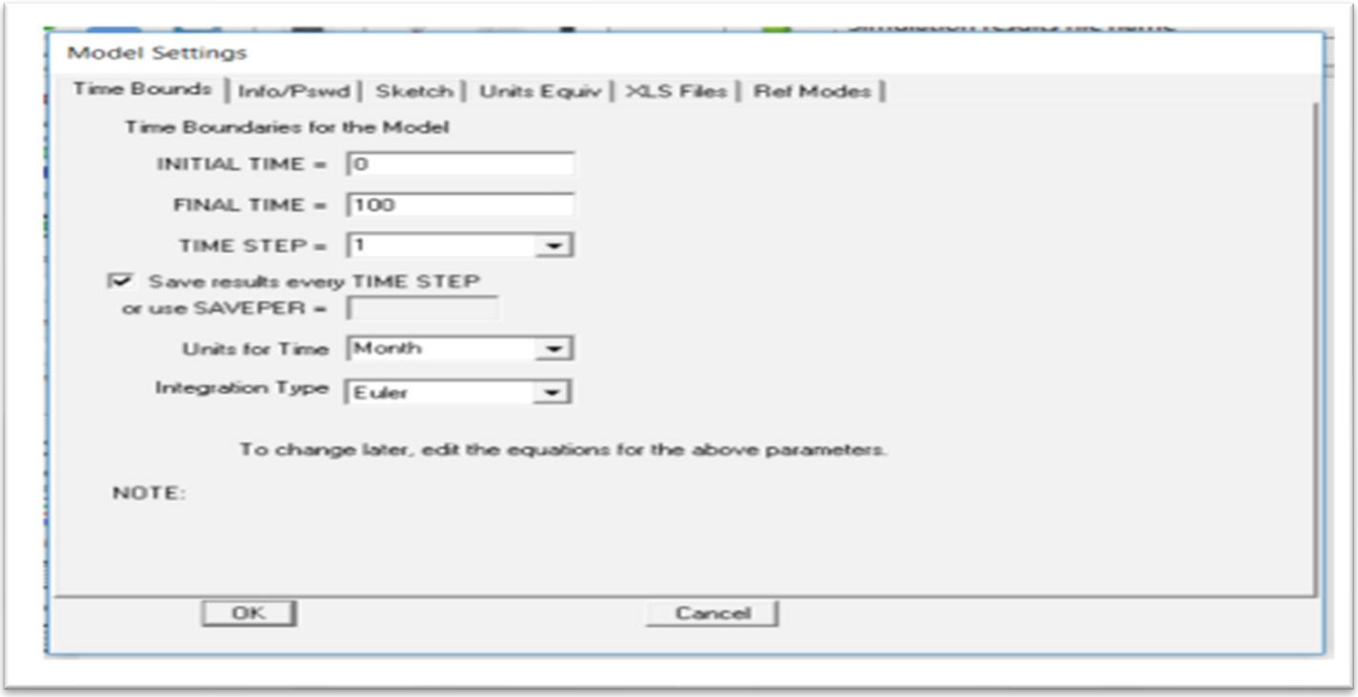


Figure 13:Modelling Settings Window, VENSIM

IV.7.4 *Flow and Stock*

Flow is something that is connected in or out of a stock. The sinking thing could be more or less anything that is measurable, like CO2, vehicles, etc..., up to more conceptual things like perceptions and behaviors, e.g., confidence. Normally it will be measured as a rate, e.g., vehicles / year (Freeman. R and all, 2013). The figure at the bottom shows the flow in the system dynamic. The stock is something that accumulates a flow, or where a flow comes from. Since an accumulation of a flow is integration, the units of action are generally not recorded as rates, i.e., not against time.

Generally, the stock represents the interest of the system which is considered as the "state" of a system.

Figure 14:Flow and Stock

Frontier System is represented by a cloud symbol and the source or sink of a flow is outside the concern of the system of interest, as in the figure 16.

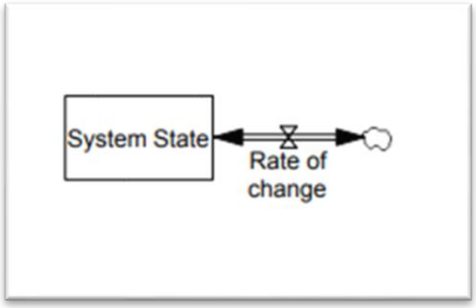


Figure 15:Frontier System

IV.7.5 *Causal loops*

Causal loop or feedback loop that has causal influence in a model to create, for example A causes B, B causes C, ... W causes A (figure 17). Then the causal loop of Diagram is a diagram of such feedback loops (Yearworth. M, 2014b).

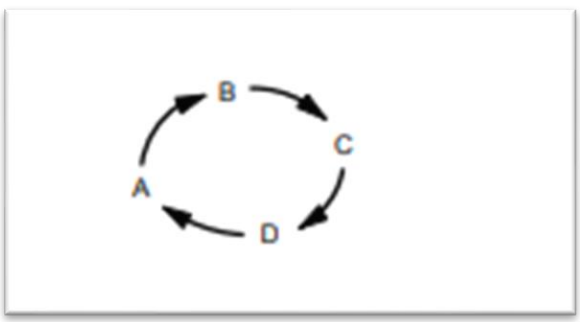


Figure 16:Causal loops

IV.7.6 *Between the causal, there is an influence, negative or positive.*

The causal influences between X and A are positive, as X increases (decreases) A increases (decreases) i.e., they go in the same direction. If B causes Z with negative influence, then, all other things being equal, as B increases (decreases) Z decreases (increases), i.e., they move in the opposite direction as show the figure.19

Figure 17: Influence between the causal loops diagram.

IV.7.7 *Features of the loops*

Features of the loops on the way the loop was formed, clockwise, circle, hexagonal diamond shape, etc. In the comment box is used to comment or add information to the loop. The figure on the right, which specified for the search, that these are variables with different values in order to be represented in the form of a graph, as shown in the Figure below.
The Electric Model was formed on the VENSIM software, so the link between the variables and all inter-connected things was formed in order to be explained to one another.

•

IV.8 Reporting Phase

It is the last step for in this chapter which explains, interprets and gives the result in the research. This is very important because it allows the public to read the important information in the field of study. Which means that all important information should be communicated in public and published for the support of an energy policy.

V. RESULTS AND DISCUSSION

Sidi-Bel Abbes is one of the hottest Wilaya in Algeria which reaches a maximum temperature of 35 to 45. The study was carried out in the specific area where there is the neighborhood which has little information about the subject of studies. In addition, among the 9,328,744 inhabitants who live in this Wilaya, 200 people were surveyed in order to have reliable data. Some people have experienced difficulty in answering each question because, on the one hand, on the means of communication, most of the people speak in Arabic and they cannot understand the question well; on the other hand, on the sanitary barrier, as we already know about covid-19, people are afraid of risking to respond our question.

In fact, the types of data collection are a type of sample surveys where questions are asked and one or more people are answered. The results of the people questioned will be analyzed and discussed on the basis of data collected during the surveys and other information and observation in the neighborhood and to the office electrical manager.

This chapter represents the result after the field study to better understand the socio-economic and demographic characteristics of the population in the study area, the electricity situation including the perception and acceptance of technology by consumers and prosumers, and finally the creation of the model for Dynamics Electricity Supply and Market P2P (MDESMP2P) in order to analyze the socio-economic environmental impacts and to carry out the comparative study of the benefit of blockchain-based P2P.

V.1 Socio-economic and demographic of the Population

Generally, it has been observed that this city is very calm, there is not the richest or the poorest but most of them live in a better condition of life which includes five to six the average in a household.

V.1.1 *Gender, number of the respondents in each household*

According to studies, we noted that 60% of our responders are men and the rest are women. This can say that there is a small gap between the number of women and men. Among the respondents, 38% are fathers in the family, 12% are mothers, 20% are the sons in the household, 26% are daughters, and the rest are the other parents or spouse who represents 1% and 2% respectively. This confirms that the information collected has a quality of data with its reliability and usable in all the continuations of the analysis. Thus, the father of the family who answers the questionnaire more, that is to say that they provide quality information

V.1.2 *Age of the Population*

We have classified 4 age categories, under 18 are classified as children, between 19 to 29 are classified as Young, between 30 to 50 are classified as adult and over 50 are classified as Seniors.

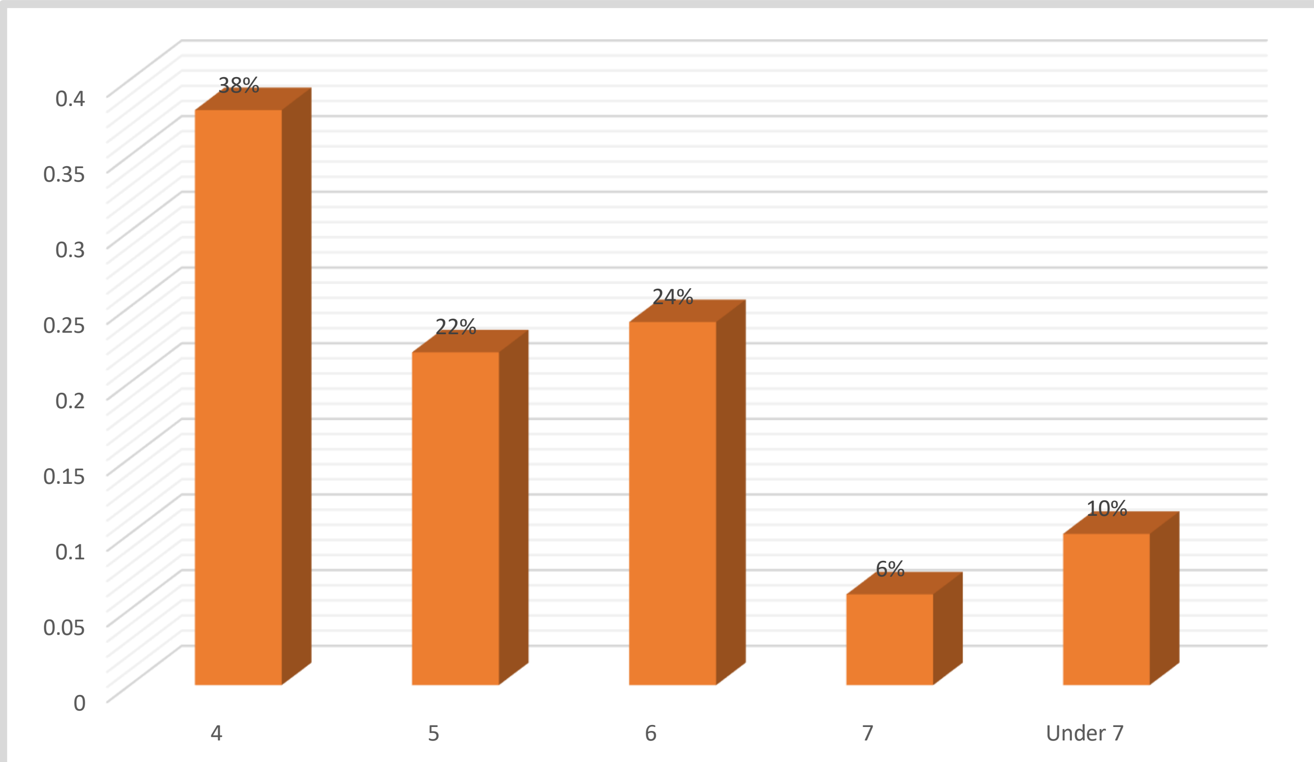
It has been noted that most of the surveyed population are all young between 19 and 29 years old with the percentage of 52%, then adults between 30 and 50 years old which represents 28%, over 50 years old it is 18% finally the least. 18 years old are passable 2%. This verifies that in Algeria, young people represent the majority of the population.

V.1.3 *Family members number*

We take as a minimum 4-person member who lives in a home and the maximum is more than 7 people.

We found that 4 members in the family who occupied the maximum percentage with 38%, followed by 6 members with 24%, 5 member 22%, More than 5 member 10% and the statistic after the survey shows that 7 members is the lowest percentage with 7%. In Algeria, since 1965 until 2016, the population has increased by 40.4 million, and by maintaining, in 2021, it has increased to 43 million inhabitants which represents that the total number of the population reaches 44,917,584. This phenomenon explains the reason for the variation of the member of the people in each family with 6 people the average

Figure 18:Family member's number, data sources: Primary Data



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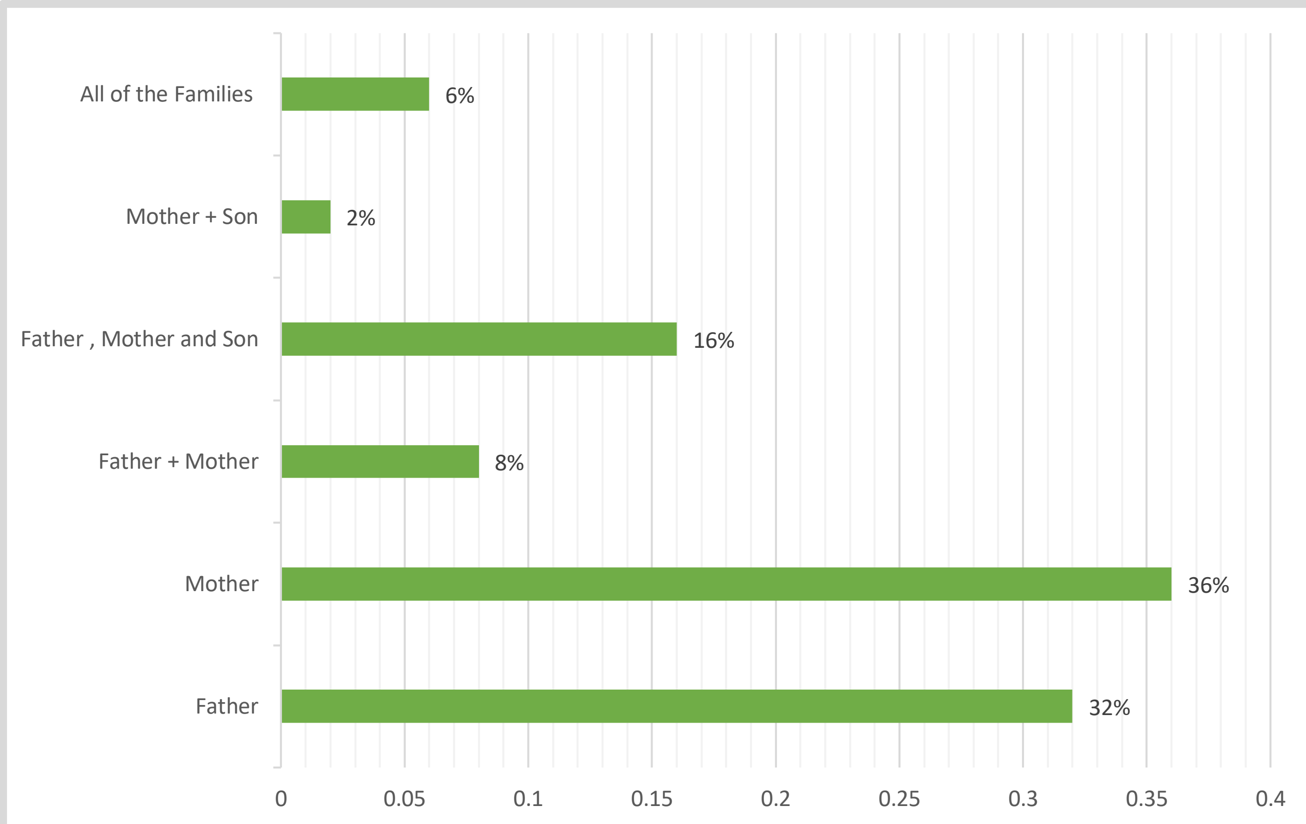
V.1.4 *Number of working families*

Usually, each family has more than 1 person working after the field survey. The following table 25 represents the number of people working in each family. In the abscissa axes of this graph is the scale from 0 to 0.4 and in the ordinate axes the types of people.

Figure 19:Number of working families, data sources: Primary Data



According to this graph, we find that the mother who has a maximum workforce of 36%, that is to say that in this community it is the mother only of the family who works more compared to the other and she works alone. Thus, only the father of the family who is next with the 32%, and only 8% of the population have been verified that the parents work together. It has also been observed that there are sons who are already working with their parents with the rate of 16%. The other family member who is have been busy, i.e., in labor is 6%.

Between 2010 and 2021, the unemployment rate in Algeria to increase more sharply by 15% according to the statistical preference center is the reason that explains why only the mother of the family or the father in the family who works alone in a House. This increased unemployment rate is due to the covid-19 pandemic, according to the survey there are many people who are unemployed, who do not have exactly what to do.

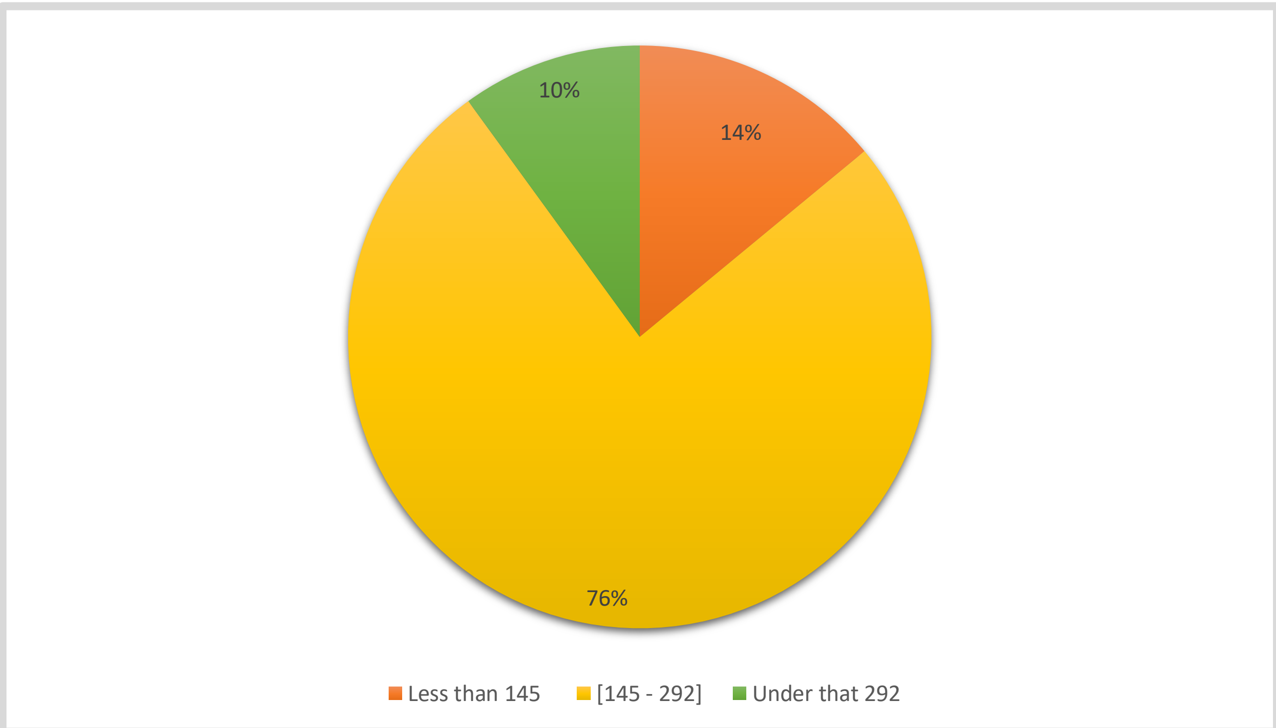
According to the survey, the average with 16% is the combination of father, mother and son, which means that most of the young people are still studying, going to school or university, more precisely the level of education is better with a literacy rate of 8.71 which is reduced according to the (ONAEA).

Finally, the life expectancy of Algerians is 77.5 years and this is the reason why elderly people or other members of the family have a rate of 6%.

V.1.5 *Average income per capita*

According to article 1 in the labor law in Algeria, the guaranteed national minimum wage was fixed at 20,000 dinars with a weekly working time of 40 hours, equivalent to 173.33 hours per month. This is why we have fixed 145 dollars equivalent to 20,000 dinars as the minimum wage and suppose that between 145 dollars and 292 dollars the average wage, which explains in more detail the percentage Average income per capita in the figure (26).

Figure 20:Average income per capital, data sources Primary Data



The circular diagram shows that 76% of the population has an income of less than or equal to the guaranteed minimum national salary of 20,000 dinars is equivalent to 145 dollars per month; while 14% of the population who receive average income between 20,000 and 40,000 dinars equals 145 to 292 dollars per month, and the remainder 10% are wage earners over 40,000 dinars equals over 292 dollars per month.

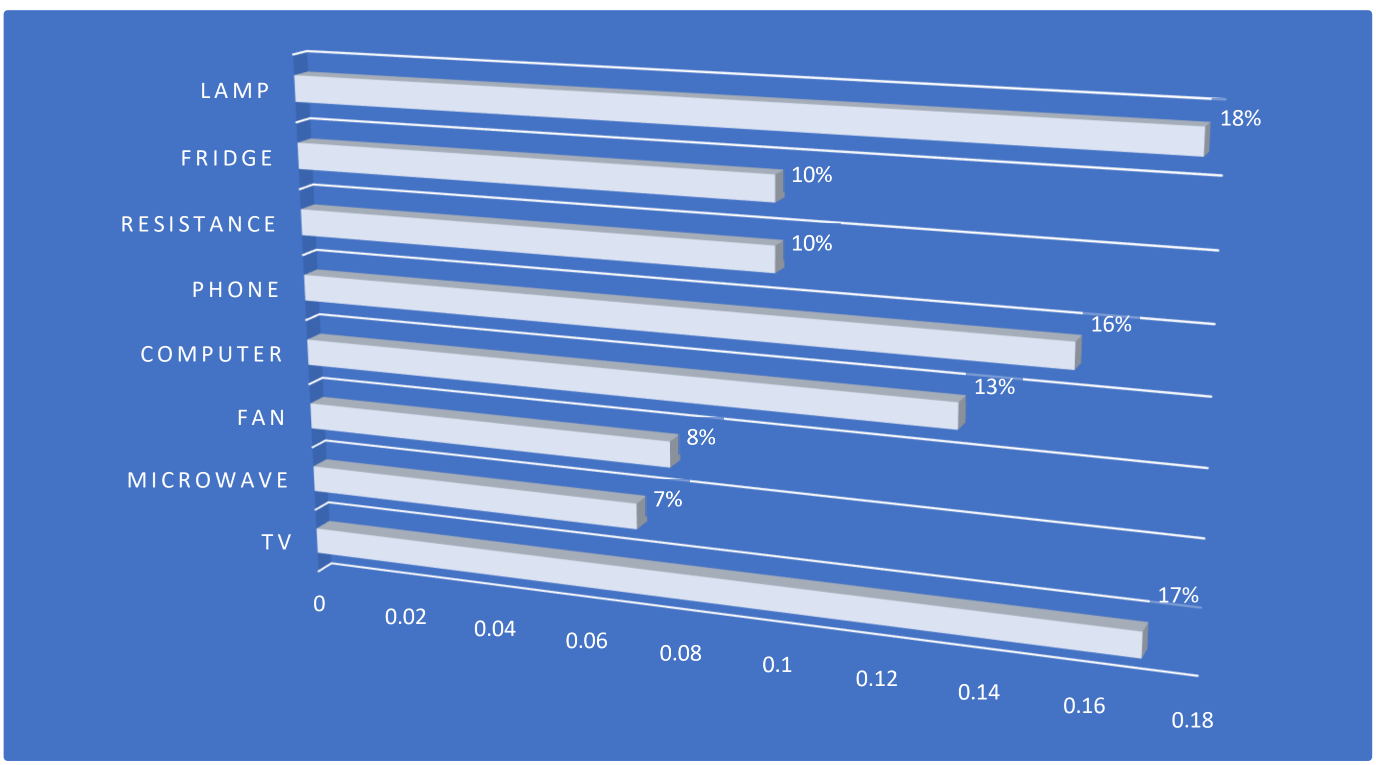
From observation, the standard of living in Algeria is average and even if there is an increase in the unemployed, this level of income classified as the lowest can be supported by each household.

V.2 Electricity Characteristics

V.2.1 *Electricity appliances*

We have mentioned in the survey all current electrical appliances and we need all these data in order to classify by the multi-tiers of the population. The graph at the bottom represents the types of electrical devices with their respective percentages.

Figure 21:Electricity appliances, data sources: Primary Data

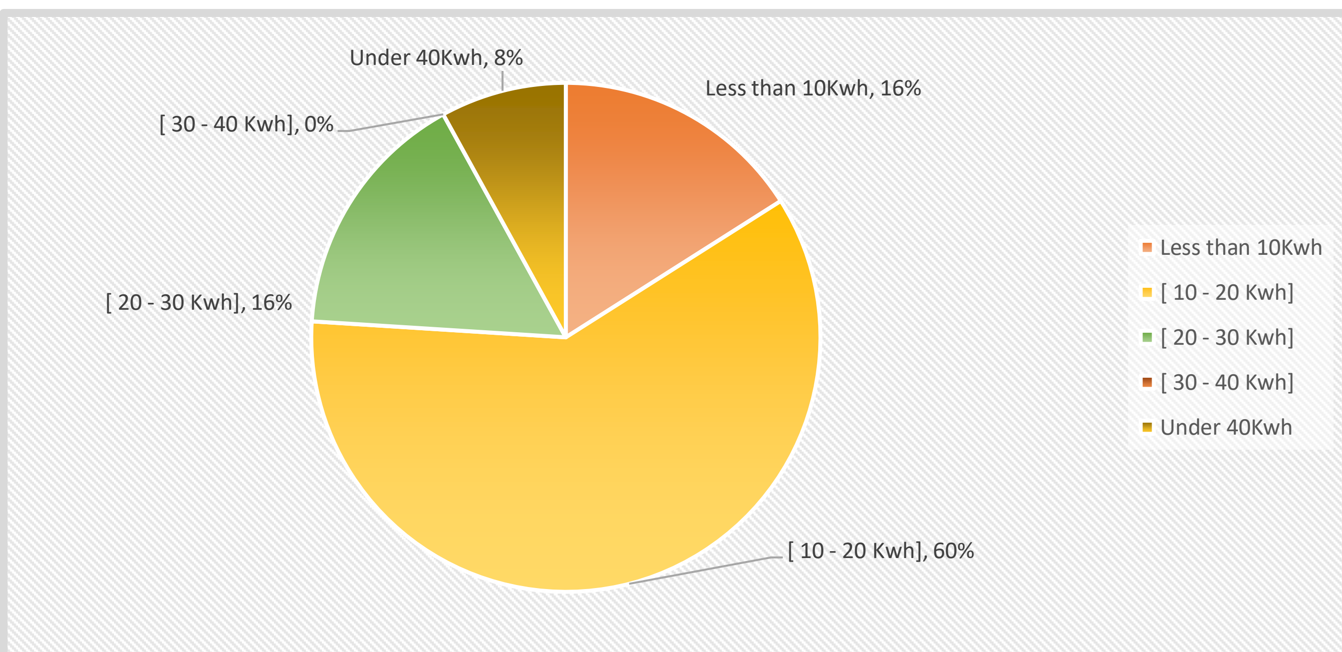


The Lamp and the television which hold as the most usable devices with a percentage of 18% and 17% each, that is to say that each household has these devices and which are considered as the most usable. Then, it is the telephone with a difference of 1% and the computer which holds the third place with a percentage of 13%. The fridge and resistance are materials with the same percentage of 10% that are considered the average, which is why the share of the population have access to these materials. 8% of the population use the ventilator for the reason with the hot climate and humid every year in month July -August roughly between 35-45 degree. Microwaves are classified as the least used equipment with a percentage of 7%. During the investigation, a few people mentioned other materials such as routers, heaters and blander are classified under other materials.

V.2.2 *Energy Consumption*

We also looked at the energy consumption of each family in order to know the rate of access to energy, particularly Electricity. This data is useful in order to build the table of multi-Tiers framework to know the level of the third of each Household.

Figure 22:Energy Consumption, data sources: Primary Data

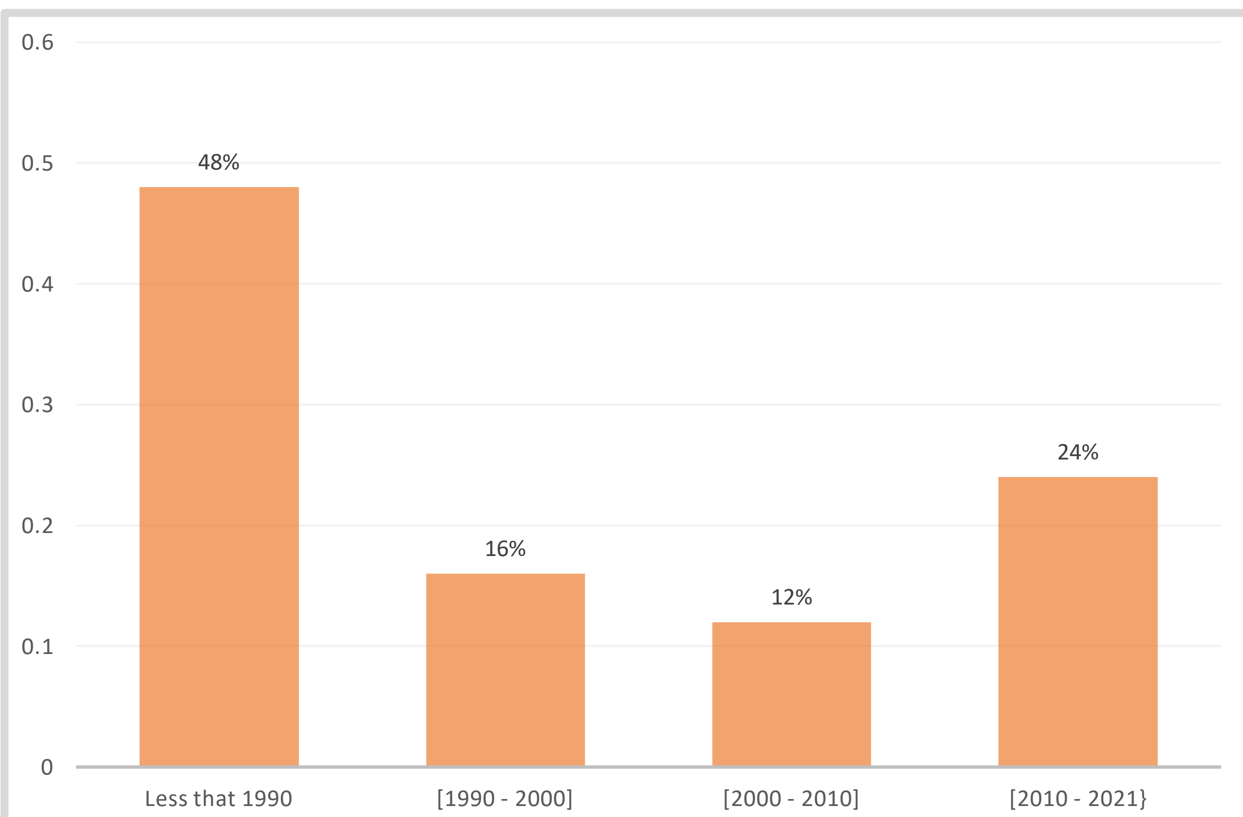


We find that 60% of the population consumes between 10 - 20 Kwh, 16% between 20 -30 Kwh and less than 10 and 8% more than 40Kwh. A small note that there are not people who consume in 30 - 40 for the reason the gap between the devices uses. The figure(22) better explains the data interpreted above.

V.2.3 *Electricity from National Grid*

The figure 29 represents the electricity access from National Grid where the years are represented in axis of abscise and the scale between 0 to 0.6 in the ordinate axis. 48% of the population are classified as the oldest which connect with the National Grid, 24% between year 2010 and 2021, 26% between 1990 and 2000 and the 12% between year 2000 and 2010. What singles out that almost the share of the people has been connected with the Algerian company of electricity and gas in SONELGAZ since 1990.

Figure 23:Electricity from national Grid, data sources: Primary Data



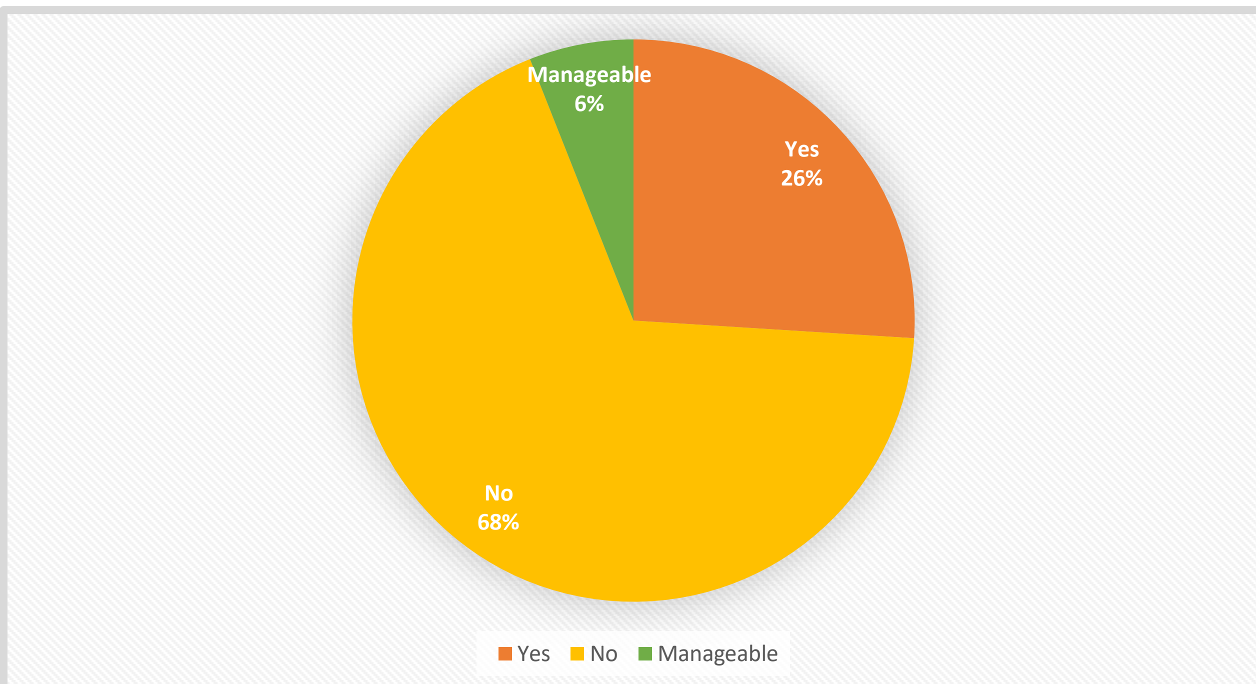
V.2.4 *The price of electricity*

The price of electricity varies depending on the technology used by each household and each hour it consumes. After the survey, we find that 68% of the population are not satisfied with the price of electricity, 26% who agree and the rest 6% are answered that the price is manageable. The electricity tariff in Algeria is very expensive for people who cannot cover their needs every day.

According to a speech by Mohamaed Arkab Chairman and CEO of Sonelgaz on October 05, 2021, he considers it imperative to review its pricing, explaining that the current prices do not allow Sonelgaz to ensure self-financing of its program Investment. By adding that the differential between the production cost 0,08732 Dollar / KWh (12 DA / KWh) and the consumer price which is 0.02911 (4 DA), is borne by the State. For then, the increase is possible in the future within the framework of the revision of the system of subsidies.

But we found that according to the survey, 45% of the population pays less than 0.07177 dolars / KWh, 43% between 0.007177 to 0.145 DA / KWh, 6% more than 0.2183 Dollars / KWh and 4% between 0.145 - 0.2183 Dollars / KWh.

Figure 24:The electricity prices Affordability, data sources: primary Data



V.2.5 The Multi-Tier Framework concept (MTF)

The design of the Multi-Tier Framework (MTF) is to measure access to energy, moving from traditional measurement for connection or not to access to electricity, thus solid fuels for cooking or no. This MTF was launched by the Energy Sector Management Assistance Program (ESMAP) in order to collect country-level data and analyzes to know all the details of the level of access to energy (Electricity) by Households and to reinforce the good practice of energy policies.

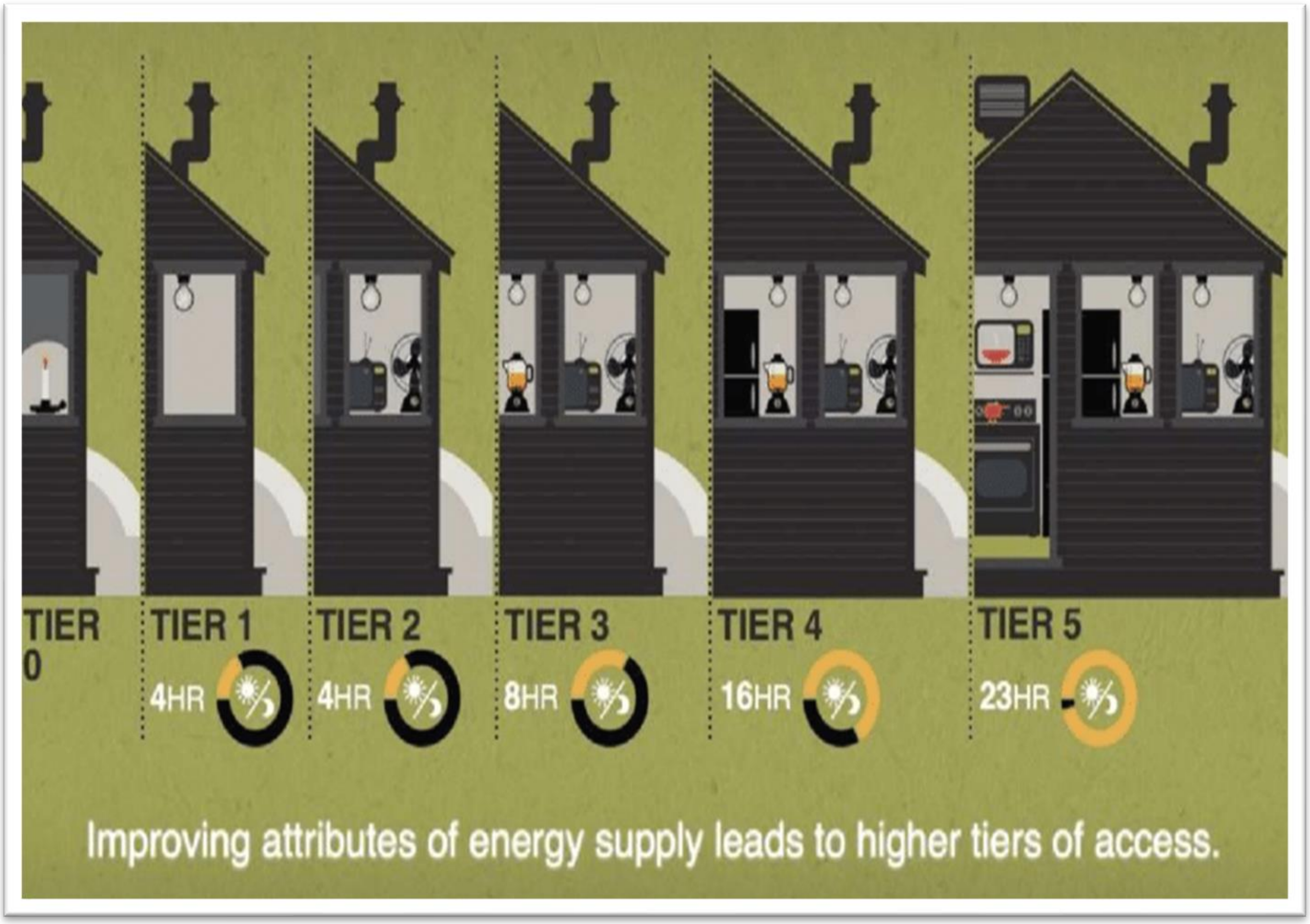


Figure 25:Multi-Tier Framework.

By this figure (25) below, access to energy is classified by level like tier 0, tier 1, tier 2, tier 3, tier 4 and tier 5. So, level 0 means no use of energy. electricity, tier 1 represents the use of 1 lamp for

4 hours; tier 2 includes 1 television, 1 lamp and 1 fan for four hours; tier 3 means the family uses 2 lights, 1 TV, 1 fan and 1 blender for 8 hours; tier 4 includes 2 lamps, 1 TV, 1 fan, 1 blender and 1 refrigerator for 16 hours; and tier 5 defines 2 lamps, 1 television, 1 fan, 1 mixer, 1 refrigerator and 1 resistance.

There are also three types of thresholds in this MTF, the first threshold is the technological one where they understand the capacity and the duration in order to determine how the households are affected by the electricity supply for each Household. The second is the economic threshold which includes the affordability of electricity and its impact on household expenditure and finally the only physical one concerns the dimensions of reliability and quality to examine the physical access to electricity for each housework. The table ... at the bottom shows the three thresholds and the frame matrix with the five tires and the electrical charge assigned to each tire.

According to the data obtained after the survey in conjunction with the multi-tier framework (MTF) tables, we see that the last three levels (Tier 3, Tier 4 and Tier 5) are classified as the population in the study area. Almost every household uses more than two lamps, TV, 1 blender and fan and Fridge depending on the minimum consumption of 1.0 Kwh (tier 3) and the realization of the seven dimensions of the frame matrix. The duration is very high except for the random cut and some unforeseen breakdown, and we can say that the quality is very good at level 3 is more, therefore, the price of electricity is not affordable by every household after data at the top (Electricity affordability), so tier 3 is still legalized because almost the majority of the population is connected to the national grid according to the data collected in the Electricity access for National Grid section. According to the information gathered by the group discussion of people, there is not yet an accident in the past or risk of accident for the future to the access to electricity in the study area.

To conclude, the Multi-Tier Framework for the study area is classified from tier 3 which was one of the best especially in Africa.

V.3 Perception and experience on new technology in energy market

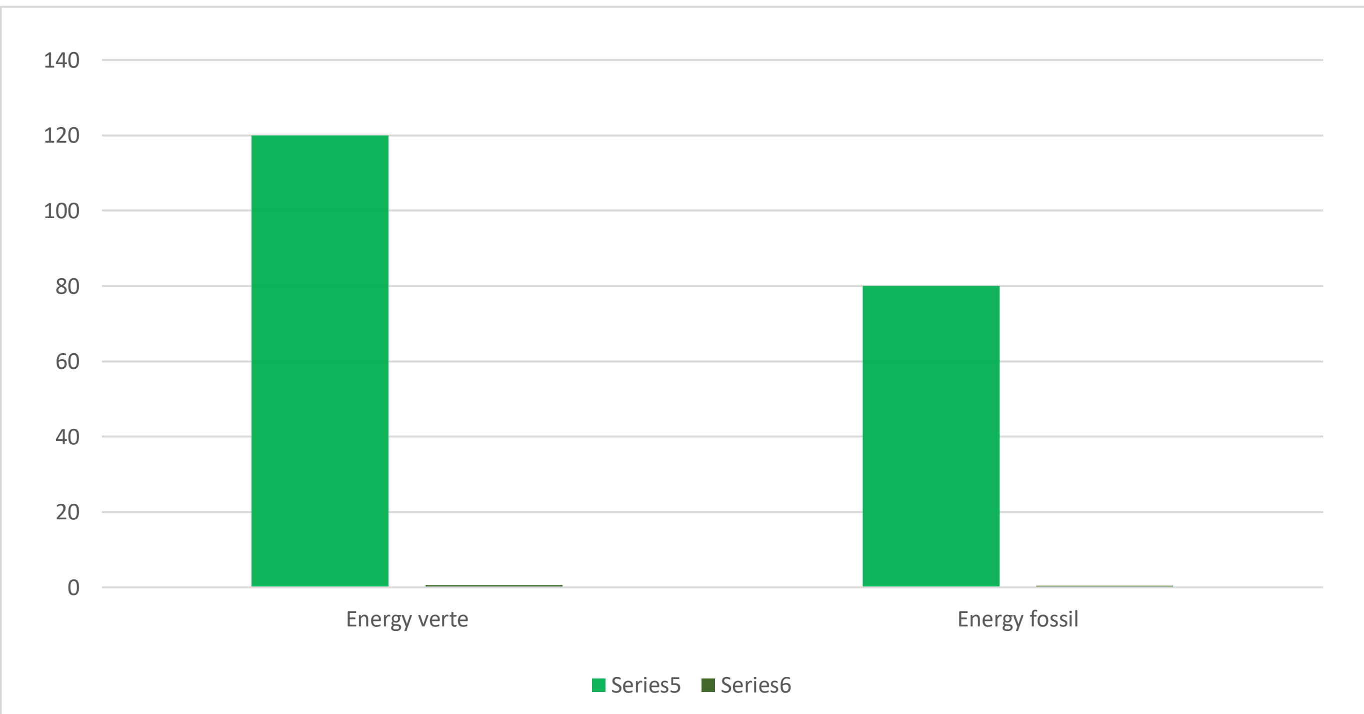
This aims to know the perception and experience of respondents on the new P2P energy trading technology. Generally, Sidi Bel Labes is one of the wilaya under development in the technological sector. Many people have been using smartphones or computers as a means of communication. In addition, there is not exactly an energy market in the study case, only the energy trade comes from the National company. We will then assess the perception and acceptance of respondents to this proposed new technology.

V.3.1 Preference between green energy and fossil energy

The graph (29) shows the preference between green energy and fossil energy of populations. Among the 200 respondents, there were 120 (60%) people who relied on the choice of green energy and only 80 (40%) people who decided to use fossil energy.

We checked when almost most people have flown change towards green energy and also affirm in figure (28) on the choice of renewable energy.

Figure 26: Preference between green energy and fossil energy, data sources: Primary data



V.3.2 Preference between P2P system and traditional energy company

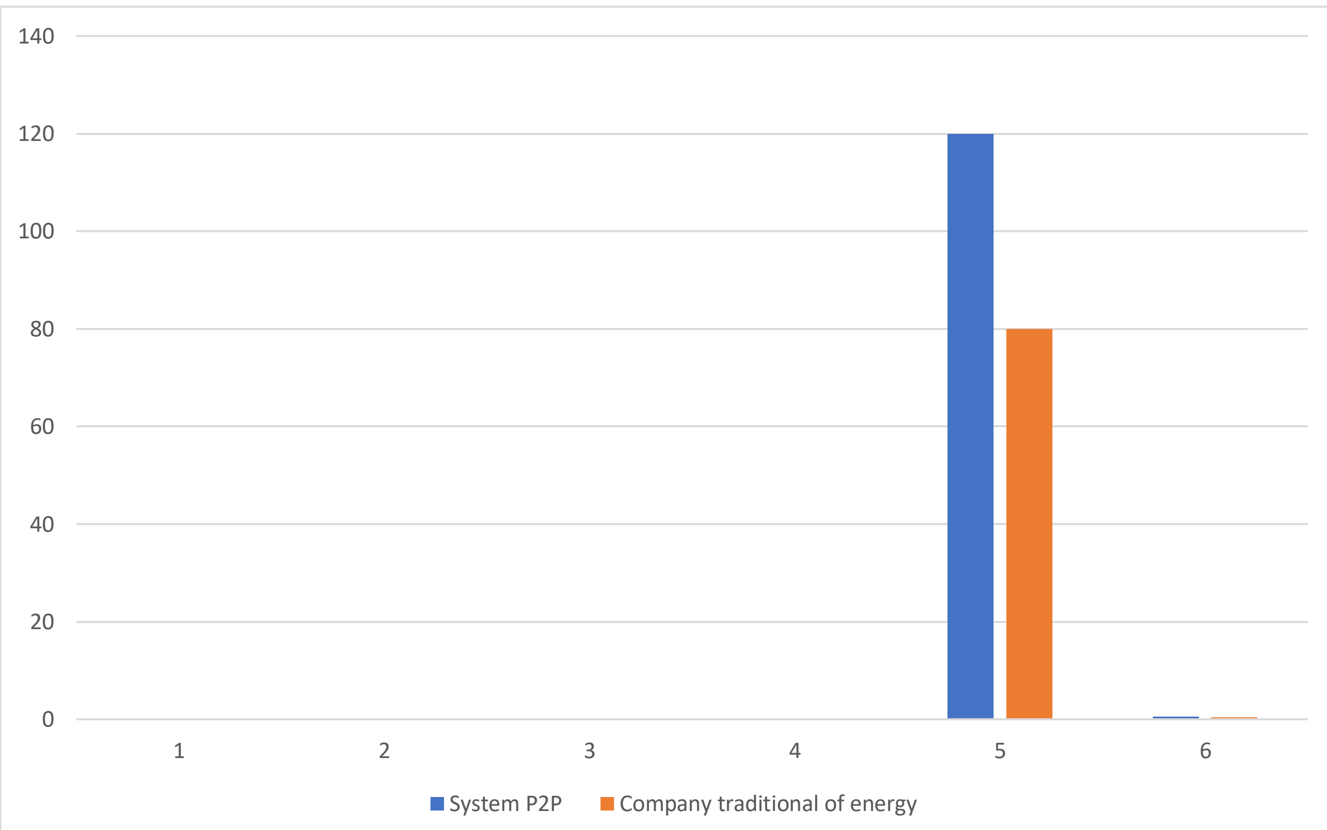
We find in figure (30) the perceptions of the populations between the P2P system and traditional energy company.

the blue color diagram indicates the total number of respondents who are interested in the P2P system and the orange color was preferred to stay on traditional energy.

the histogram shows that 60% of the populations are expected to be interested in the new system while the rest are preferred over the traditional energy company.

Almost the average of the population was interested in the P2P system, the others who do not have exactly the choice, according to the survey.

Figure 27:Choice between System P2P and Company, Data sources: primary data



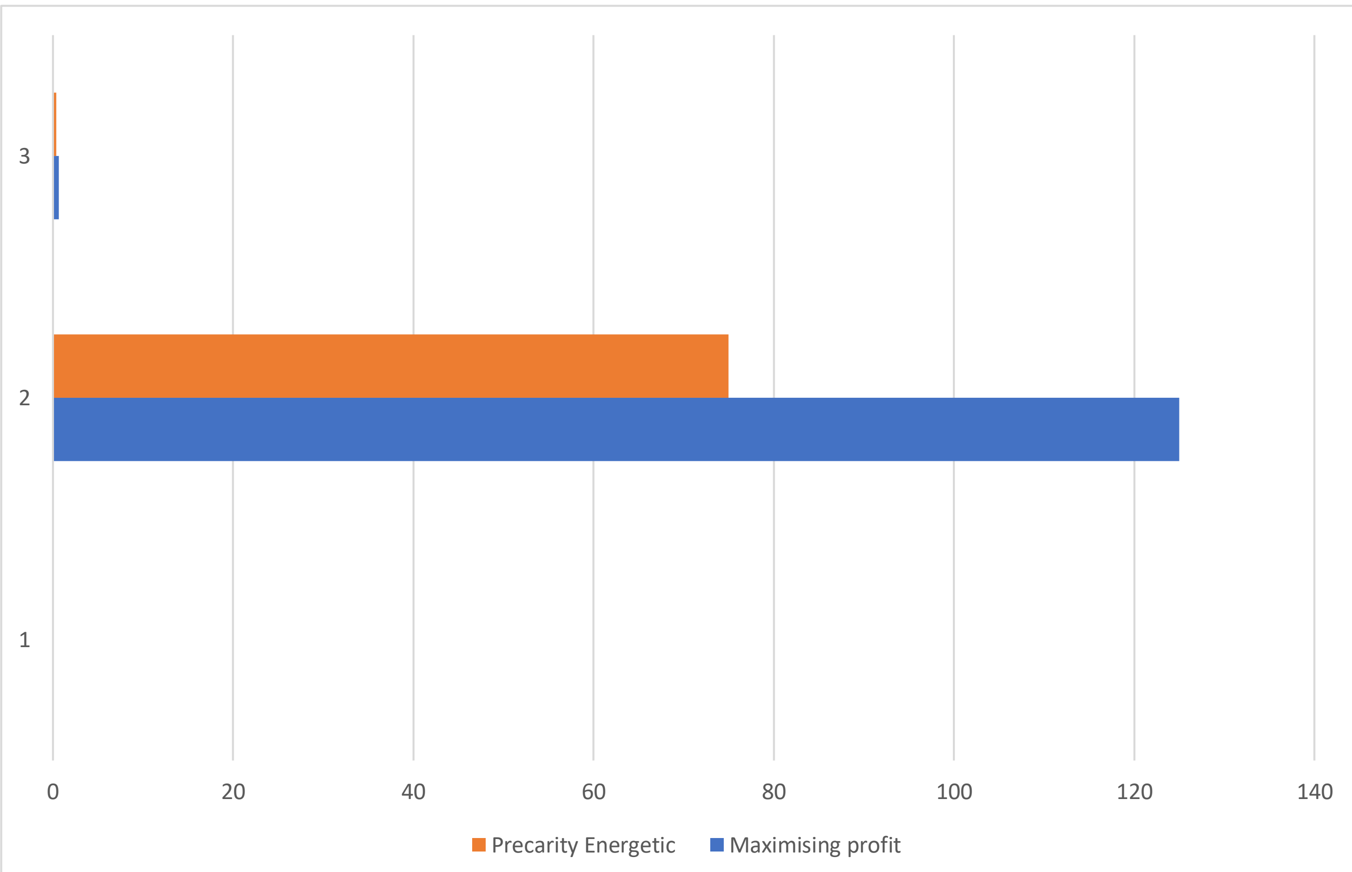
V.3.3 The goal of using energy

This part explains the objective of each Menage for the choice of use of energy trading especially of the P2P system. We questioned whether a person wants to maximize their profit in order to increase their income or just contribute to fuel poverty.

In the graph (31), 62.5% chose to maximize their profit with the color blue, while the rest focus on the second choice.

This result confirms the reason for the low income for each household. The implementation of this project can then increase the income of each Household.

Figure 28:Increase the Income vs contribute to fuel poverty, Data sources: Primary data



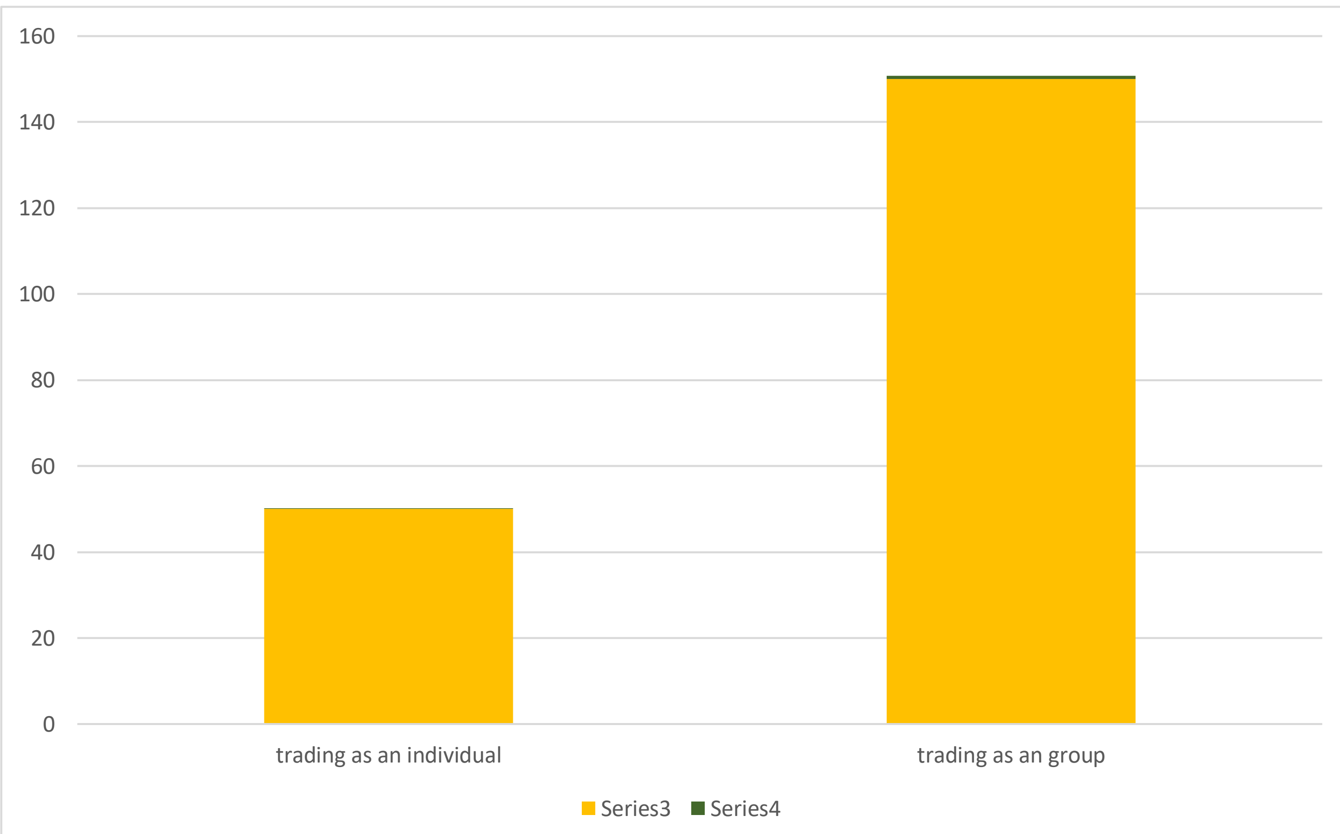
V.3.4 Choice between trading

Finally, it is essential to know the population's choice for trading. We have adopted two choices, one trading in a group and the other are individual, more details on figure (32).

It has been observed that 75% of the population prefer to do group trading and 25% prefer individually.

The reason is that each population prefer better to come together.

Figure 29:Trading individual or in group, Data sources: Primary Data



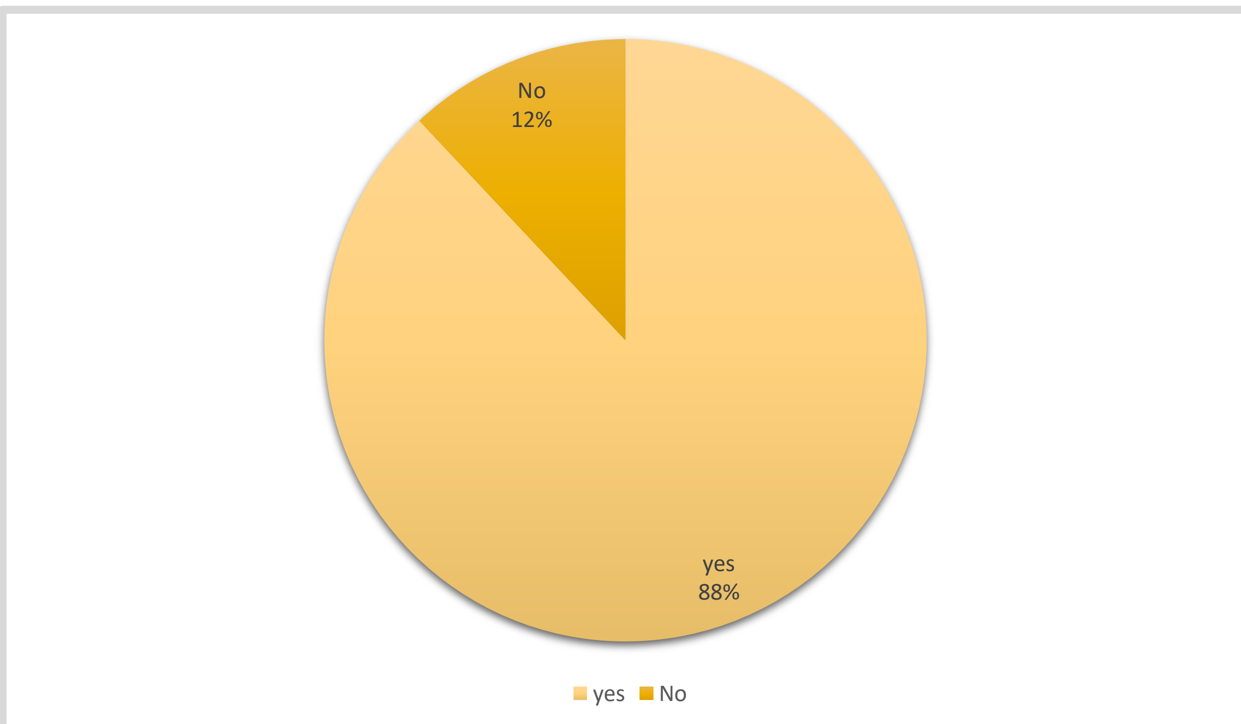
V.3.5 Conclusion of this section: Acceptance of the Blockchain P2P

Australia is a Favorable Country for the use of solar photovoltaics, more than 2 million PV are already installed which results as the world first of the highest proportion of prosumers. To then ensure efficient energy access for all, shifting to the two-way energy flow that allows peer-to-peer trading is one of the best strategies to achieve the goal (Barbara Albert, 2018).

In Algeria, according to the field study, there is a project that was underway for the installation of PV by the State but the difference compared to those in Australia that there are not enough prosumers, most Households are attached to the national network (according to the data on electricity access from the national grid).

And after the explanation of the new peer-to-peer trading technology (Virtual Net Metering) like energy sharing is where one party produces excess electricity and then shares this with another party, thus after discussion with a few groups of people residing in the study area and the field survey 88% of the population were accepted to implement this new technology. The rest who responded to prefer not to choose this technology are, on the one hand because of the lack of notion on computer technology, on the other hand, they have concerns about the transaction between virtual pairs, finally, they do not have confidence in the new technology of the means of payment.

Figure 30:the percentage of acceptance of the technology, data sources: Primary Data



V.4 Modeling approach for energy policy assessment on the peer-to-peer energy system

Energy policy is a decision taken by the responsible authorities after analyzing all the socio-economic and environmental feasibility. To have a good decision by referring to the scale on the economy, the policy must be based on the modeling approach on the dynamic system of energy, economy and environment.

Some scholars in the systems dynamics group have found that modeling systems dynamics can provide policy information on the interactions of different variables such as energy, economy and environment. For example, the dynamic models developed by Ford in 1983 and Nail in 1992 have been applied to the design and evaluation of energy policy. investments and uncertainty developed by Ford in 1985 and Quadrat-Ullah in 2005, conservation policy analysis created by Ford and Bull.

In the following sections, we will explain the system dynamics model that has been developed to better understand the evaluation of energy policy for the per-to-per energy trading market system, particularly related to electricity supply; thus, to analyze the data of historical evolution and present situation of electricity.

V.4.1 *The Dynamic model*

Electricity is a form of energy that we will use most of the time. This electricity often comes to the National or central distributor. The notion of P2P electricity trading emerged to facilitate distribution but also to encourage people to use renewable energy. Some trader also called “Uber” or “Airbnb” of the energy, because it of a platform where the producers of energy have a surplus and they can distribute to sell with an acceptance of the price between the two participants (Prosumers and consumers).

The figure at the bottom represents the p2p trading power sharing system which are interconnected between the different variables. This dynamic system was formed according to two constant variables "Unit cost of technology and Unit others cost", Four auxiliary "Investment, time, contraction delay and price ', four flow" Electricity production, capacity of production end

Production sold and production rate "and four stocks" Generation of Prosumers, Self-production, Distribution on the Market P2P and Generation of Consumers ". In the first, production electricity is formed according to Unity cost technology, investment and time; production capacity is determined from generation and construction delay; then there are two paths between after production, one is self-consumption and the surplus intended to be distributed on the market to consumers, or production balance is determined on the unit of the other cost, price and the generation share after self-consumption.

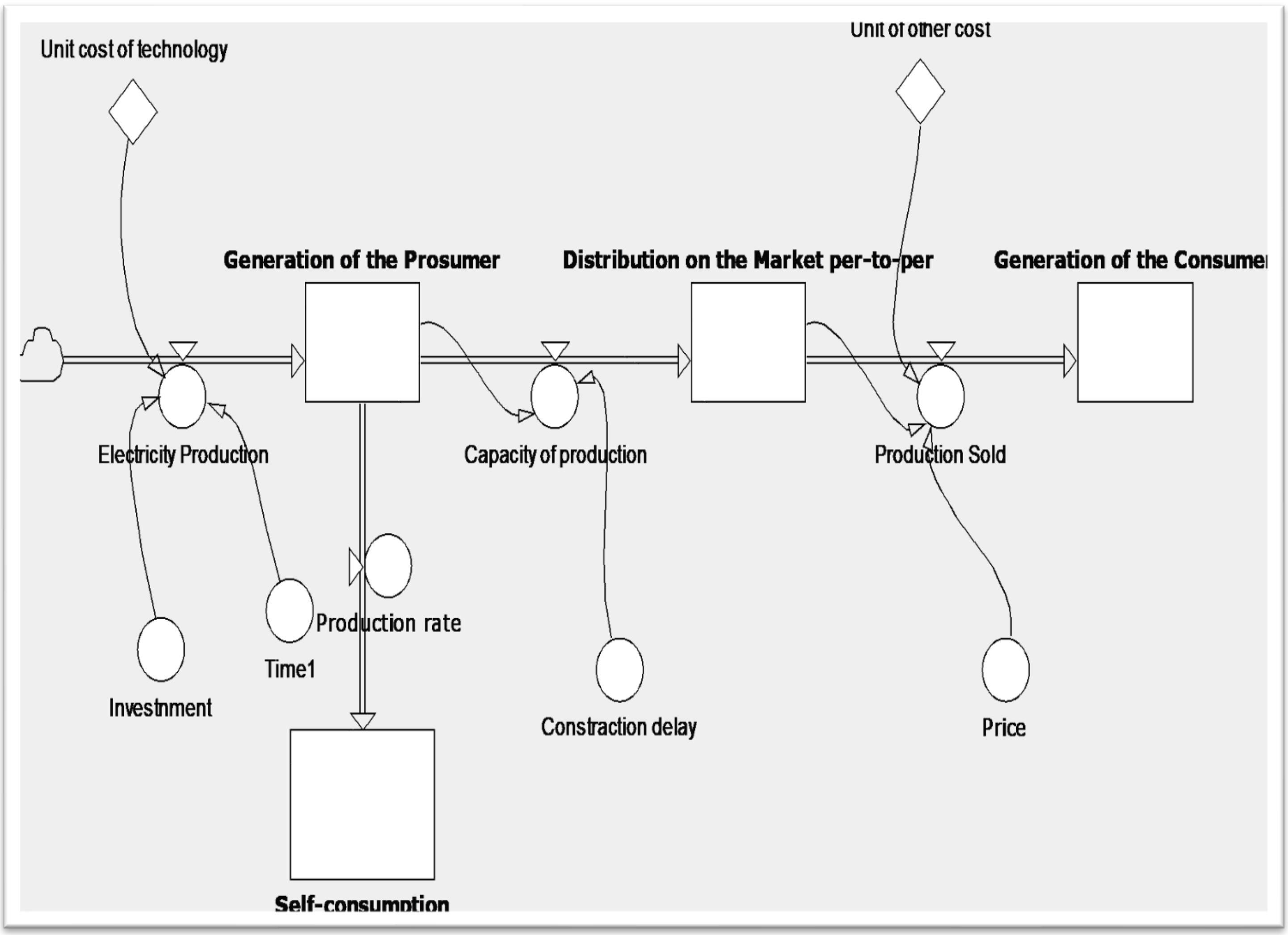


Figure 31:System dynamic model of electricity and peer-to-peer market.

The following model is a cause-effect relationship of the variables of the electricity system when considering the system per-to-per-energy system. The results are based on three criteria such as

Economic, Social and Environmental, and the model is based on the economic, electricity and P2P market sectors. There are positive and negative loops in this model with Seven main variables: Electricity Demand Sector, Electricity Production Sector, Investment and Production Capital sectors, Environment Sector, Dynamics of political incentives such as Share of technology and Dynamics of endogenous pricing of electricity, finally the causal-loop diagram of the electricity market per-to-per systems.

V.4.2 *Electricity Demand Sector*

Economic growth is the exogenous variable in this model which has an impact with the other variables. In this model, the economic sector depends on the evolution of all the other sectors within the country. Sector demand is one of the endogenous variables which occupies an important role in this model. Know that the consumption of energy like electricity is related to the demand for electricity which has an effect on the price. This means that the economy becomes stable thanks to the increase in the Revenue of each population by reducing the price of energy (electricity). In addition, when we talk about economic growth, we mean to measure by on the GDP indicators, another variable in this model has an influence on the GDP. This variable is the intensity of the demand for electricity, which explains the quantity of electricity that is consumed to obtain a unit of the GDP of the sector. So, the low intensity of demand means a potential for the degree of energy efficiency of electricity. In addition, the variables Investment, Electricity generation are all variables which has a positive cause and effect to strengthen the demand for energy from electricity. The figure (31) briefly shows the causal loops diagram of the operation of the Electricity demand system.

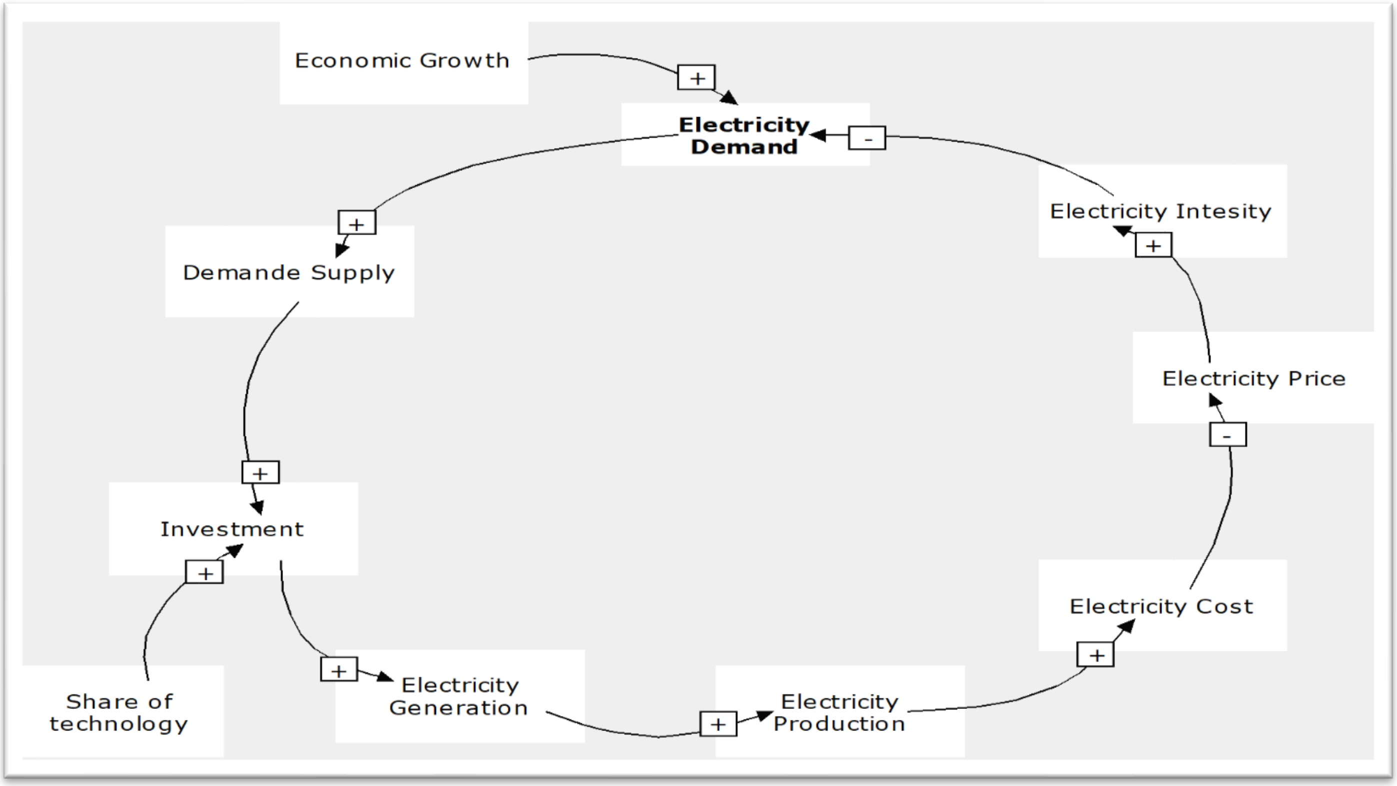


Figure 32:A causal loop diagram of electricity demand

V.4.3 *Electricity Production Sector*

The figure (32) shows the energy loop of the electricity production. We already know that the increase in demand for electricity (consumption of electric power) requires a performance of economic activity. This leads to an increase in the energy demand resources of electricity. The demand for higher resources turns into a desired capacity storage resource, leading the resource supply to increase into productive capital. The more resources we have in supply, the production of electricity improves ensuring the best affordable condition for the consumer. Electricity production is high leading to lower average production cost, which ends in lower price of electricity. And once the electricity tariff is low, consumers intend to increase their uses, thereby fortifying the initial increase in demand for electric power.

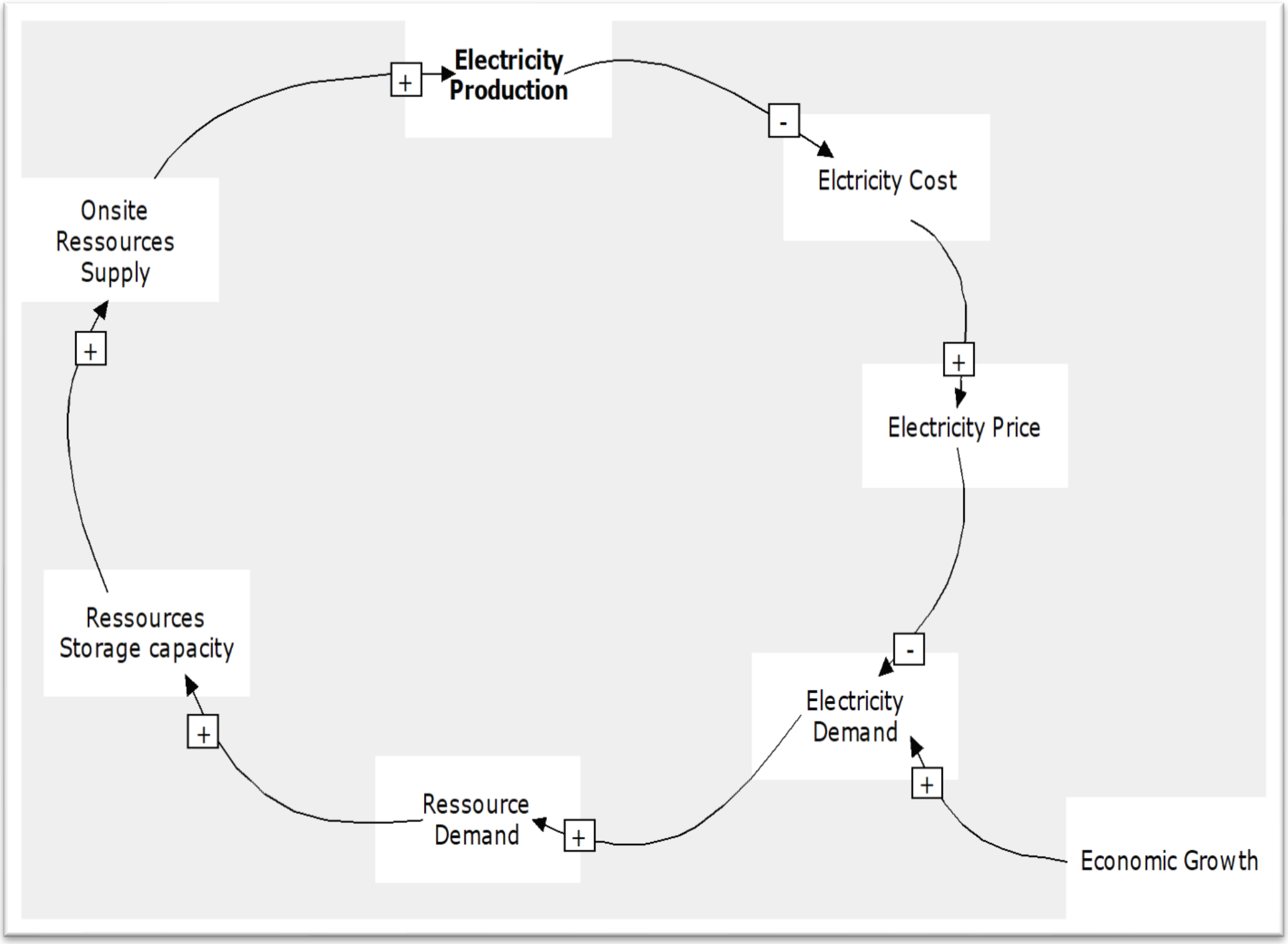


Figure 33:A causal loop diagram of electricity production.

V.4.4 Investment and Production Capital sectors

IPP investment plays an important role in the energy sector to strengthen more capital stock in technology. However, the decision to invest in a building site increases only after a certain delay. And also, the stock of operational production capacity of each technology depends on the investment rate of PPIs as well as the completion rate. So, more production capacity means more electricity produced. This means that the assumed constant investment efficiency leads to the development of thermal capacity and the reduction of production costs. The low cost of production prompted PPIs for investment, thus increasing the initial investment in this technology.

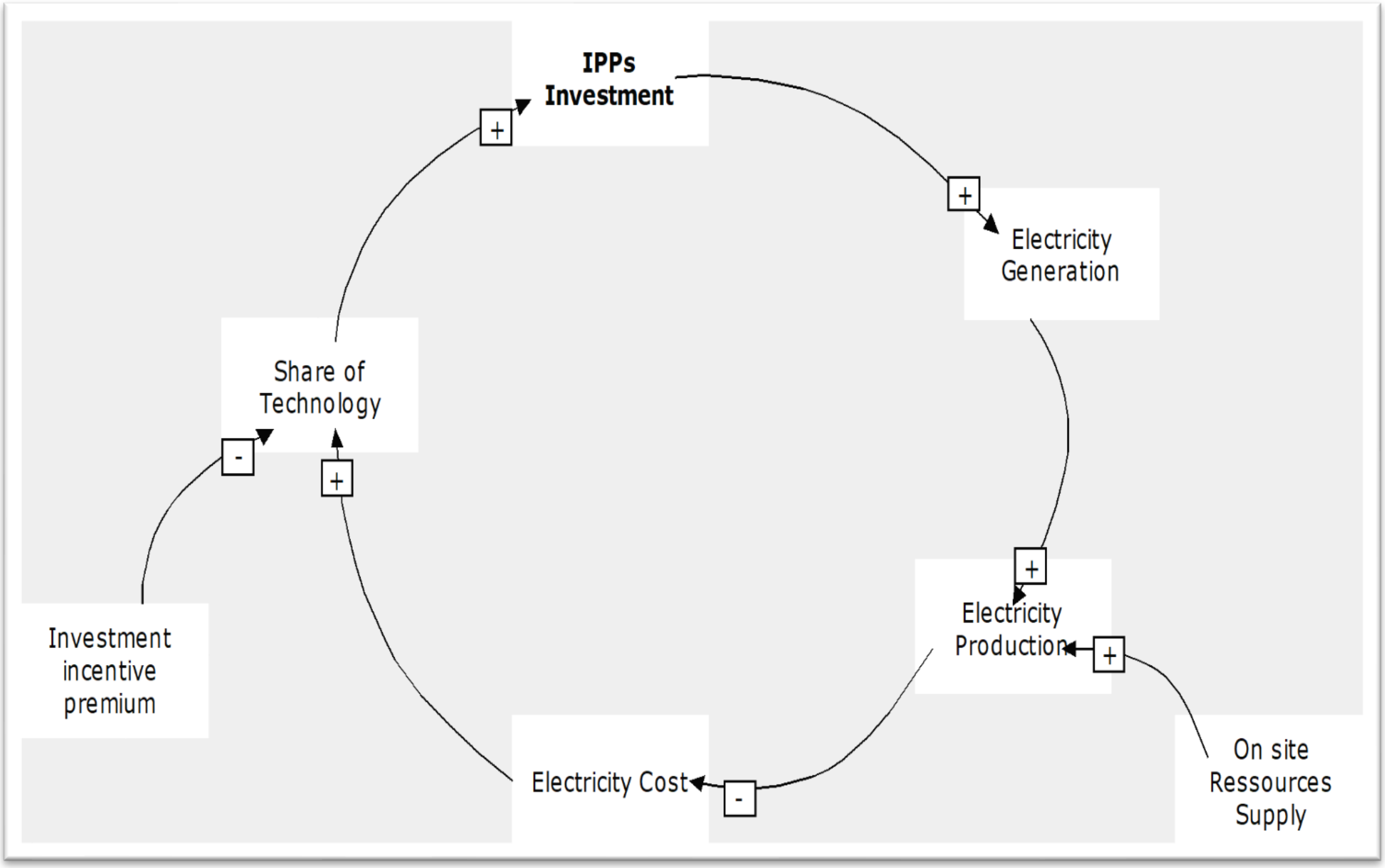


Figure 34:A causal loop diagram of investment.

V.4.5 *Environment Sector*

The figure below shows the effect of generating electricity from electricity on the environment. The development of the production of electricity increased an abundance of the emission of carbon dioxide (CO2). This is due to the use of technology for the operation of the plant, thus requires more IPP for the investment. The investment in technology involves a huge use of electricity generation. Finally, the more the electricity generation improves, the more efficient electricity production is achieved, thus returning to the initial form of production electricity.

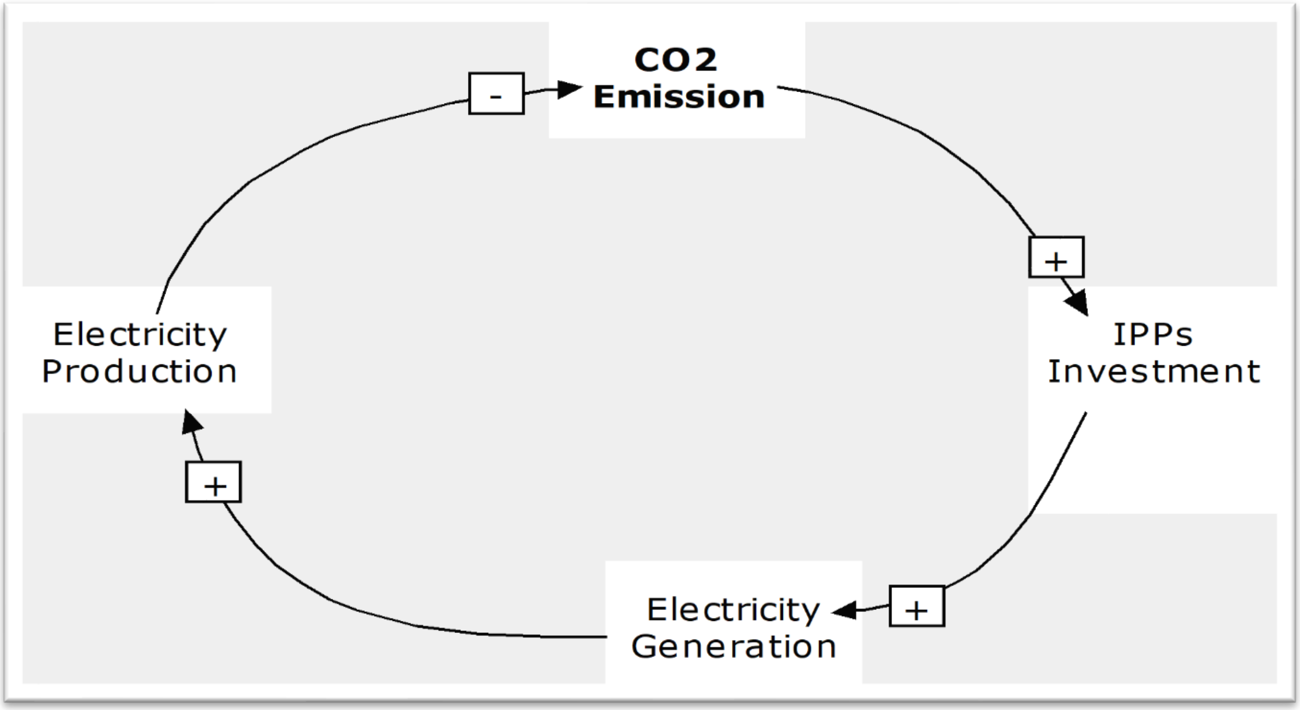


Figure 35:A causal loop diagram of CO2 Emissions.

V.4.6 *Dynamics of political incentives:*

- **Share of technology**

Technology plays a very important role in the energy sector by substituting with the investment of PPIs and the political incentive factor. The change in the capital cost of the production completion rate has an effect for each power plant technology. This means that the cost of production also suffers from this variation in cost. At the same time, the use of low-cost technology will be advantageous provided one takes into account the lifetime of the capital. In addition, the investment is amortized if the cost of producing electricity in a certain technology is relatively high. Thus, the price of electricity has also increased, i.e., the investment is risky because the estimated life is relatively lower compared to the real life of the capital). This makes the decision of investors not to invest because of their decision to invest. So, investors' short-term perspective on investments prompts PPIs to invest in other alternative technologies. And we are going to go back to the initial direction of the investment for the technology and this long-term investment of a technology can not indicate the real cost because of this risk premium. This risk premium is reflected not only in the energy sector such as the uncertainty of the price of oil, but also in changes in the socio-economic environment.

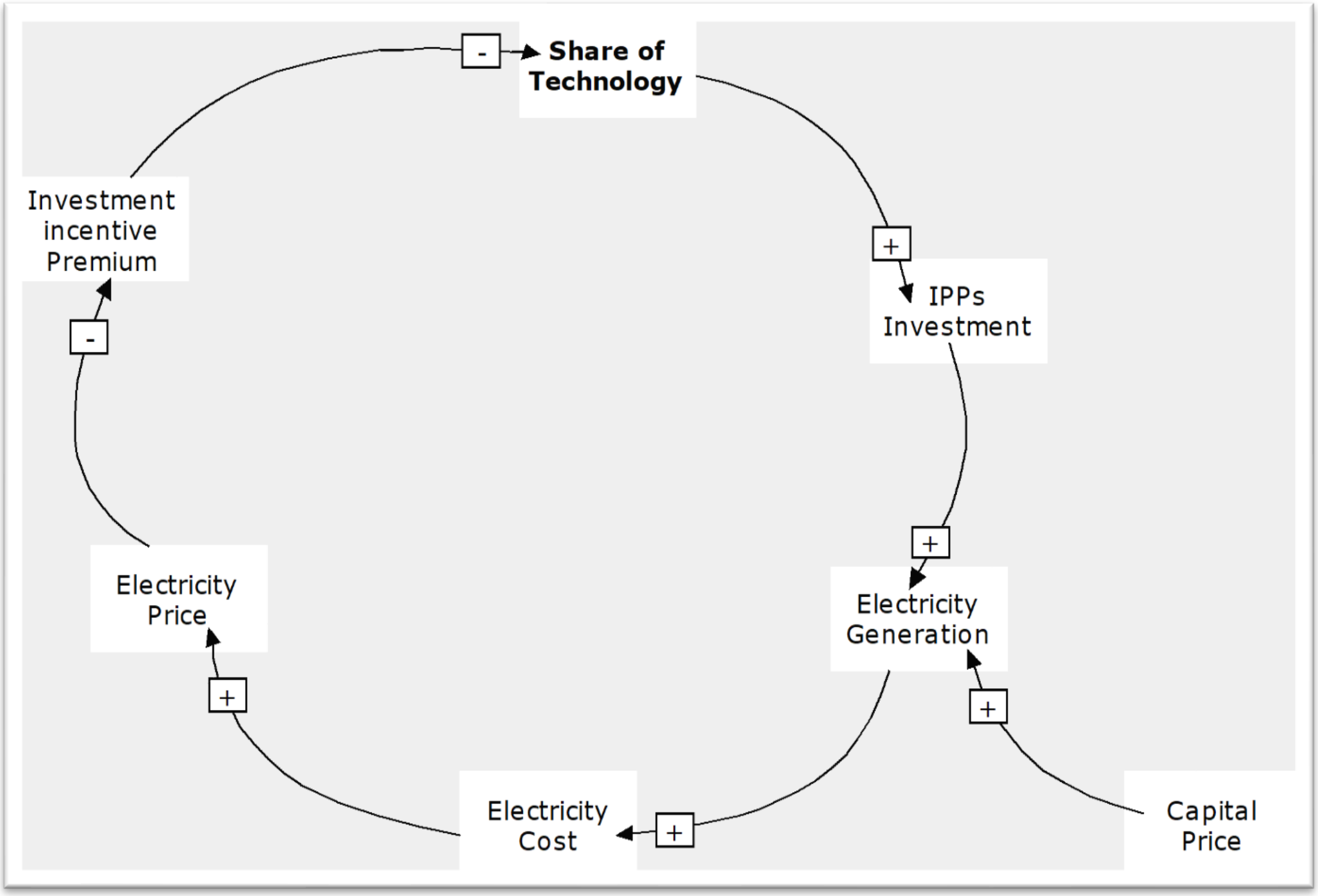


Figure 36:A causal loop diagram of Share of Technology.

- **Dynamics of endogenous pricing of electricity**

In the model, the cost of investment is a driver to stimulate all interconnected variables (endogenous to exogenous variables), including the price of electricity endogenously.

The loop represents the effect of suppressing the demand for electricity, moving from capital-intensive technology. The figure at the bottom shows more details on electricity pricing.

We will start with a positive effect on the demand for electricity on improving economic growth. The increase in the demand for capital improves the demand for productive capital. When the demand for productive capital has increased, this leads to desired capital, thus leading to an increase in PPI investments in productive capital. The increase in investment brings more capital to the existing stock. The higher the investment costs, the higher the operating costs and the higher the fuel costs lead to the increase in the cost of producing electricity in each of the technologies, thus causing the cost of electricity and the high price. The increase in the price of electricity requires consumers to consume less and this returns to the demand for roaming electricity.

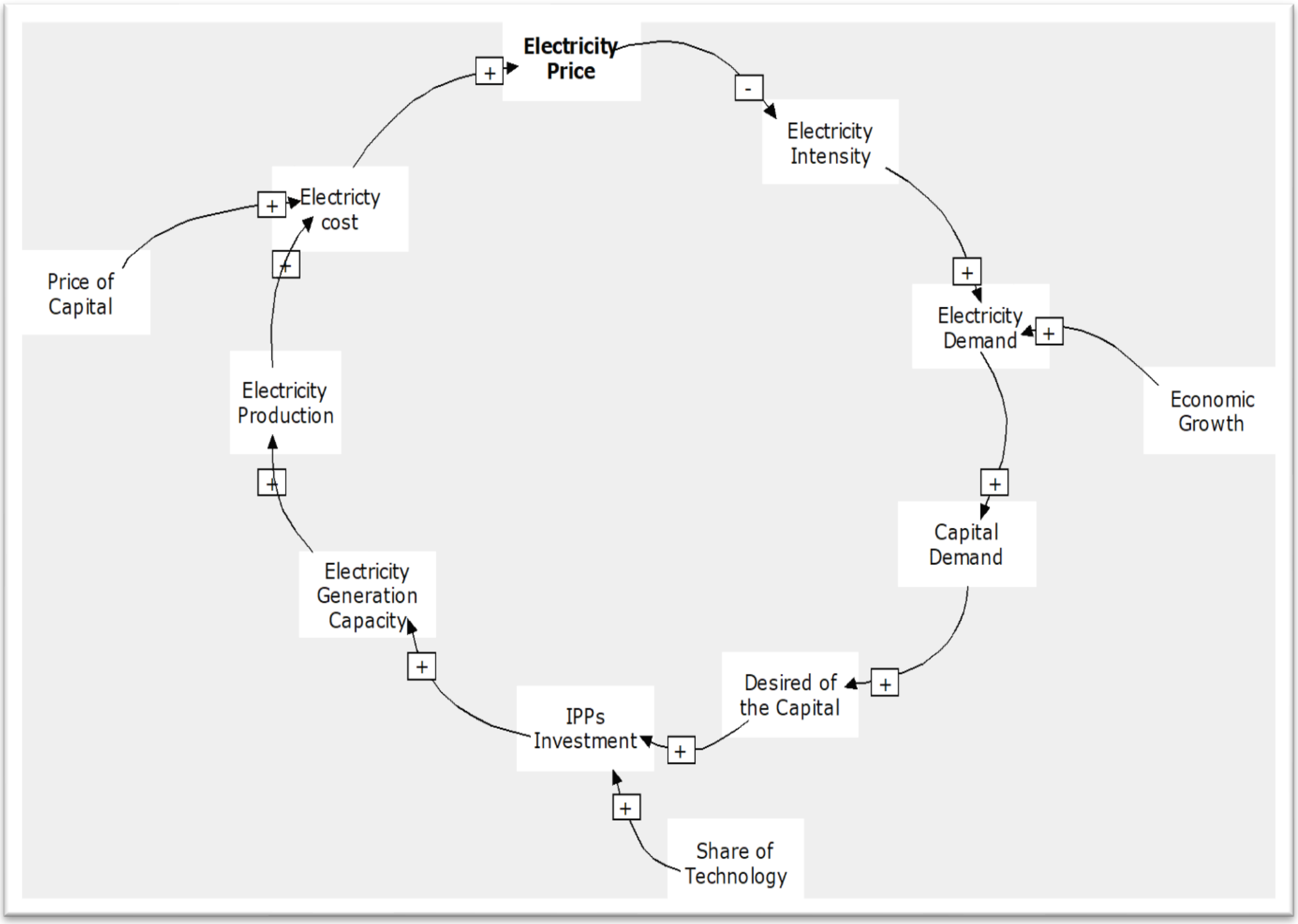


Figure 37:The causal model of electricity pricing mechanisms.

V.4.7 *The causal-loop diagram of the electricity market peer-to-peer systems.*

Figure 3 bellows illustrates the causal loop diagram of the electricity supply and demand system by integrating the per-to-per energy trading market. In this system, the intermediary is neglected but it is a transaction between the prosumers and the consumers.

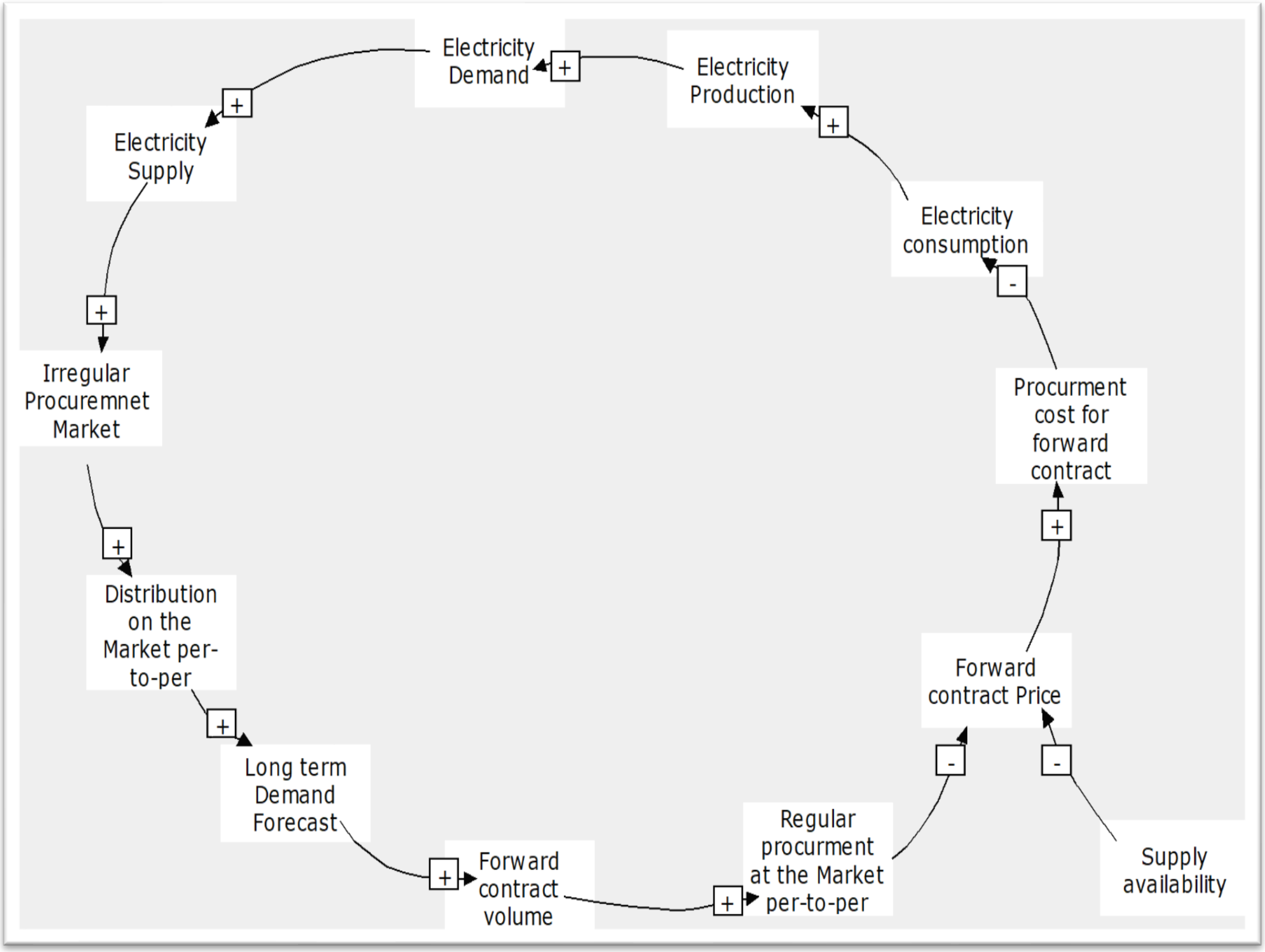


Figure 38:A causal model on market peer-to-peer of electricity.

There is a contract between these two stakeholders who can influence the supply of producers (Consumers or others), so the forward price on this market has an effect on the level of production. In a financial market, there are financial intermediaries, retailers, speculators such as hedge funds, but here in a per-to-per market, only between producers and consumers that the transaction works. Here the demand-side electricity reinforces the supply storage before supplying on the market. As a consumer, buyers see all the offers in the market which to distribute in that market with different prices and different characteristics. If the forecast is short term, we move directly to demand electricity generation. In another sense, if long term, there is a contract in the consensus process for the volume of futures contract. The validation of the contract is done only after the agreement between the parties taking, including the price of forward contract and the procurement cost for forward contract. Once the contract is concluded, the consumers have the right of access to the electricity and the level of the consumers causes a variation in the production of electricity supplied by the producers (Prosumers). The loop returns to the initial form in electricity demand which is influenced by electricity production. In the per-to-per market, the consumer can produce if he has surplus production.

V.4.8 Behavioral validity of MESAMP2P with use of Theil inequality method for the comparisons

This section is the end of the study for the validation of the MESAMP2P model. The objective is the comparison of the observed behavior of the real system with the behavior of the Model. We will use the mean squared error analysis and Theil's inequality statistics to evaluate the historical fit of MDESAMP2P. These statistics measure the gap in overall behavior. The simulation starts from year 2000 to be compared with the socio-economic environmental aspects real behavior of the energy sector in Algeria. The hypothesis on the test is:

H0= accept the error if result < 5%

H1=refuse if no

Socio-economic aspect

We try to compare the economic aspect according to the historical and simulated data of the model.

- **Price of Energy**

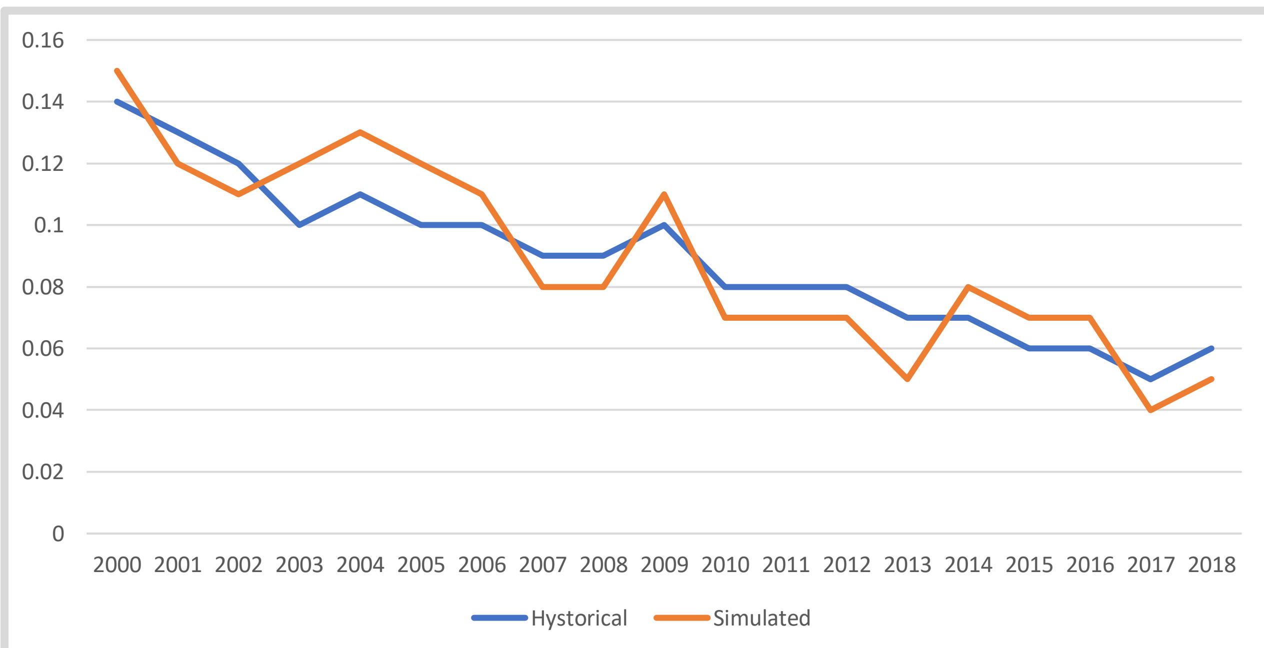
According to the result on the date of collection, we find that almost the person does not have to bear the price of electricity; moreover 0.007177 dollars is the affordable for every manage. According to the model, we find that there is just a difference in the price. We find that the error on RMS is 3% and the error on MSE is just about 1% and the remainder are for inequal variance and covariance; Then this mean that the error is acceptable. First interpretation this error can be solved by the model and the cause of this error is in principle where there is a lot of consumption, the price is necessarily increased. The intervention of the model then has an effect on the price of electricity which leads to the increase of the Revenue by each Household.

Table 4:Error Analysis

MSE	RMS	U^m	U^s	U^c
0.000182	3	0.007706	0.007706	0.277414

MSE: Mean Squared Error; RMS: Root Mean Squared; U^m, U^s, U^c are unequal variance, unequal covariance and respectively.

Figure 39:Simulated and historic price of electricity ($/kwh), Data sources: Secondary Data



- **Energy Intensity**

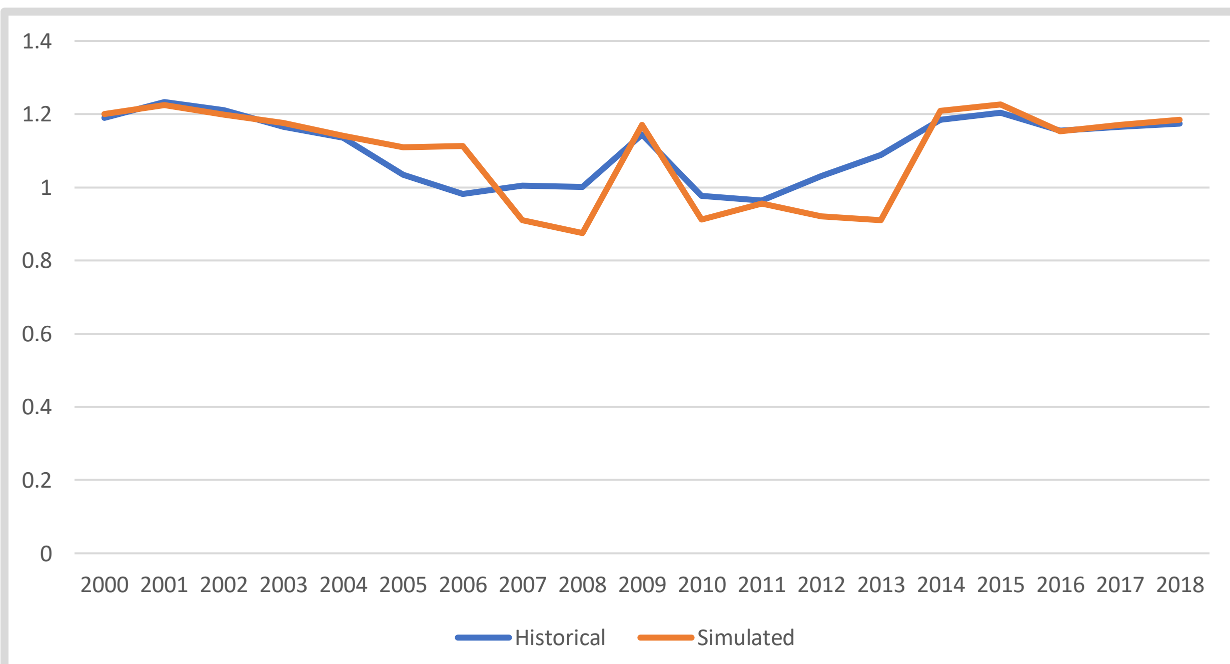
Energy intensity is the measure of energy efficiency of an economy. More precisely, the ratio between energy per unit and GDP. Here we find the value of the MSE is 1%, the error on RMS is 5% and the rest is for the other variables. We can say that this model has a positive effect on energy efficiency with this error that can be corrected from the model. The more the energy intensity increases, the more the GDP increases which favors the Economy.

Table 5:Error Analysis

Variables	MSE (units		RMS	U^m	U^s	U^c
Energy Intensity	0.005729828		5	0.017803	0.057178	0.640905

MSE: Mean Squared Error; RMS: Root Mean Squared; U^m, U^s, U^c are unequal variance, unequal covariance and respectively

Figure 40:Simulated and historic Energy Intensity (kwh), Data sources: Secondary Data



Energy aspect

- **Energy consumption**

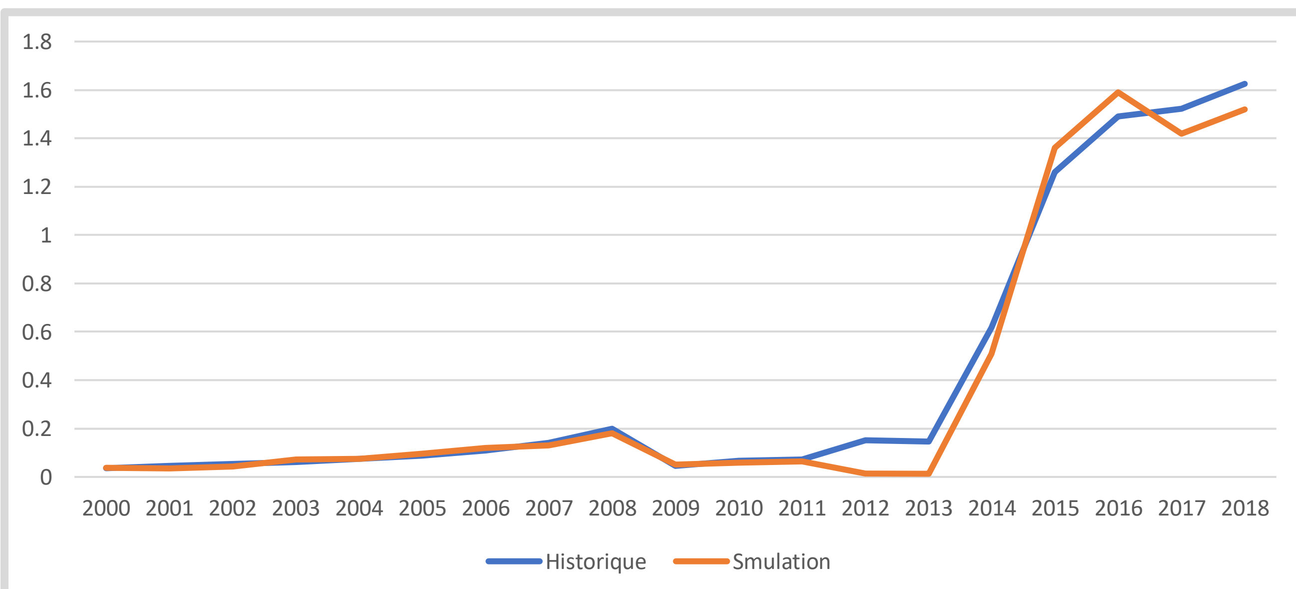
Energy consumption is the total energy consumed for each Household. We can see the error from table () that the MSE error is 0.05% and the RMS error is 3, for variance inequality and covariance are 0.41% and 0.86% respectively. The errors are logical because the MESAMP2P model can correct it for this and the power consumption is almost the same between the historical value and the simulation. In addition, this one check from the figure the model has an impact on consumption.

Table 6:Error Analysis

MSE	RMS	U^m	U^s	U^c
0.005329	2	0.41298	0.862574	14.86721

MSE: Mean Squared Error; RMS: Root Mean Squared; U^m, U^s, U^c are unequal variance, unequal covariance and respectively

Figure 41:Simulated and historic Energy consumption (TWh), Data sources: Secondary Data



- **Energy Generation**

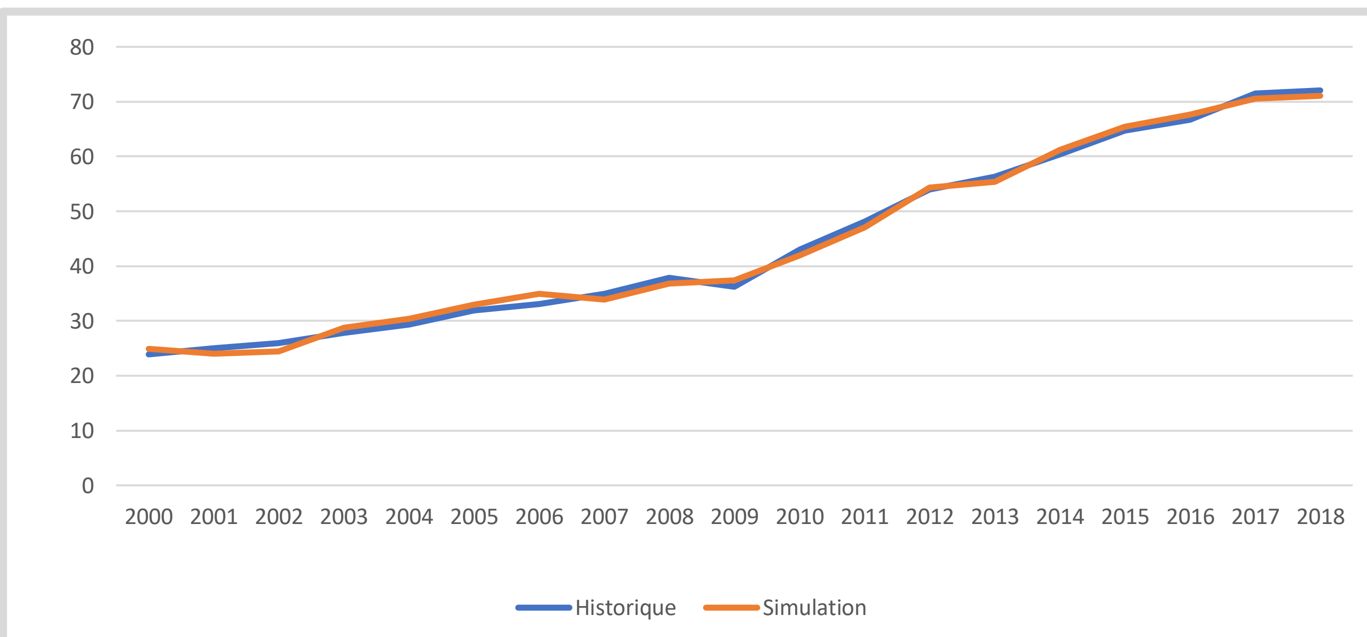
Energy generation is one of the components in energy demand. It is the process of producing electricity from energy sources. According to the test on the result of the table, the error on MSE is 1.28%, RMS is 1, the remainder are for the inequality of the variance and covariance. We then see that this model is feasible on the electricity generation because the error is almost acceptable. Thus, according to the figure, there is a small difference between the two values. The more energy generation increases, the more production increases, which means that access to electricity is achieved if the P2P trading system is used.

Table 7:Error Analysis

MSE	RMS	U^m	U^s	U^c
1.286727	1	1.234184	2.468142	41.97634

MSE: Mean Squared Error; RMS: Root Mean Squared; U^m, U^s, U^c are unequal variance, unequal covariance and respectively

Figure 42:Simulated and historic Energy generation (TWh), Data sources: Secondary Data



The results of the simulation have an impact on the energy intensity and the CO2 intensity. These variables are endogenous variables of the Model in order to verify the objective of our study "to assess the impact of investment on power generation technology and on power distribution to the P2P energy trading market in the long term. Energy intensity represents the economic behavior while the CO2 interest provides us with the CO2 emissions on electricity. We present in the table. the mean square error analysis (MSE), the root means square error in percent (RMSPE), thus the Theil inequality statistics for these two variables.

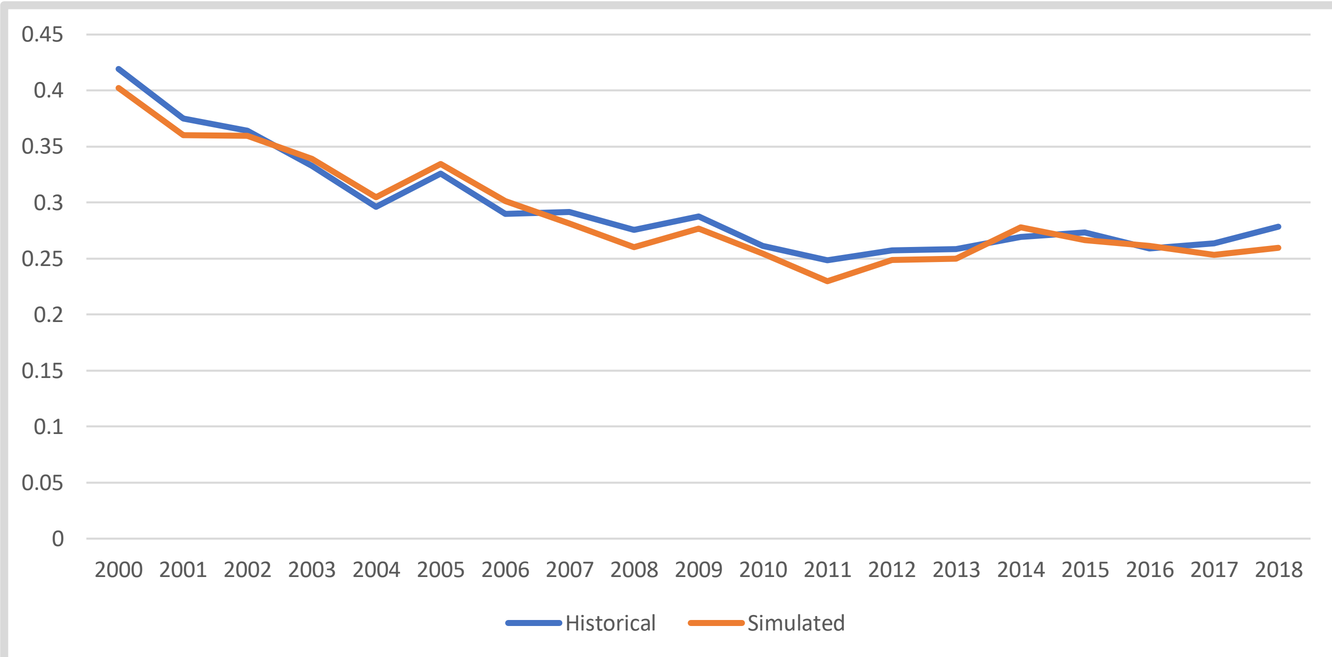
Analysis of the MSE provides us with a measure of total error and the decomposition of bias, negative variation and unequal covariations (Sterman, 1984). It is from the total error that we can draw a conclusion about the confidence of the Model. Theil's inequality statistics tell us to solve the errors through their decomposition.

Table 8:Error Analysis

Variables	MSE (units)	RMS	U^m	U^s	U^c
CO2 Intensity	0.000143059	4	0.012296	0.01646	0.442642

MSE: Mean Squared Error; RMS: Root Mean Squared; U^m, U^s, U^c are unequal variance, unequal covariance and respectively

Figure 43:Simulated and historic CO2 intensity (Kg/$). Data sources: Secondary Data



As the figure in above, we found 4% the percentage of error RMS in the intensity of CO2. The percentage of MSE is just 1%, the rest is for unequal variance and covariance. First interpretation then is that the abundance of CO2 is due to the production of electricity. For the MESAMP2P model, we can solve this problem in order to manage the acceptable value for the CO2 intensity.

Another interpretation can also be said that the MESAMP2P hypothesis from the start is in order to stimulate investment in order to produce and sell the product in a P2P energy trading market. Therefore, this causes an increase in CO2, while the model is not intended for forecasting, primarily to support policy effectiveness. The error in the intensity of the CO2 does not have much impact on the model. To conclude then, the MESAMP2P model is intended for political analysis which responds with the precision of real data.

V.5 Summarize of the socio-economic feasibility and on the dynamic model developed: “Model for Dynamics of Electricity Supply and Marche P2P(MDESMP2P)

This section analyzes and verifies the results of the data collected as well as the behavior of the model dynamic system obtained. The data are part of a deeper study on the socio-economic and environmental feasibility conditions for the solution to facilitate access to energy in every household.

First of all, before the formulation of the survey, we tried to make research and an observation about all that concerns the field of study and the field to be studied in order to have more information in the field studied. But also, in the case study, for example, one might expect that all the Households in the case of "Sidi Bel Labes" have a potential on the scale of the economy to accept (improve standard of living, social structure, unemployment rate, ...) before installing the project. To examine this phenomenon, we have mentioned the section of the Income of each Household with the number of persons employed.

Subsequently, the daily consumption of households was examined to know if the project is favorable for its installation in this city to add another central distribution of electricity. However, according to the figure (24), the daily consumption does not seem to increase with the use of the National networks which have existed for a long time according to the figure (25).

In addition, the opinion of the population on the implementation of the new technology on the P2P energy system market is very important information in order to know the rate of households who have accepted this project. According to the figure (29), almost half and more of the people all agree while the remainder have no choice.

For the model under study, the key to long-term success is strengthening through technological competence and strongly predicting the perceived satisfaction of users (Bhatia. M et al, 2018). Therefore, as long as the energy are reliable, adequate and affordable to consumer services, technical competence is assured. Apart from this case, this study has developed the MTF method to measure at which third the level of community satisfaction depends on the number of hours of supply per day, with a comparable effect of electrified and non-electrified households (Bhatia. M et al, 2018).

The quality of the services and the electricity as well as the reliability in terms of distribution and in terms of cut-off have been found to be a long-term advantage on the socio-economic and environmental. This time, the project can ensure all of this in terms of quality and reliability of services and electricity without intermediaries.

Finally, we created a dynamic simulation model MDESMP2P (Model for Dynamics of Electricity Supply and Marche P2P), capable of capturing the dynamics of the filters of the sectors of the electricity supply and distribution system.

The effect of the model causes an environmental socio-economic advantage on the electricity sector based on the P2P system. MDESMP2P is based on strong interactions between:

- energy demand models
- investments in the electricity supply sector
- capacity constraints
- emission constraints
- financial structure
- the electricity distribution processes on the P2P market

and also, MDESMP2P is feasible on all economic activity, social and electricity sector. Below are the causal loops cause and effect of MDESMP2P

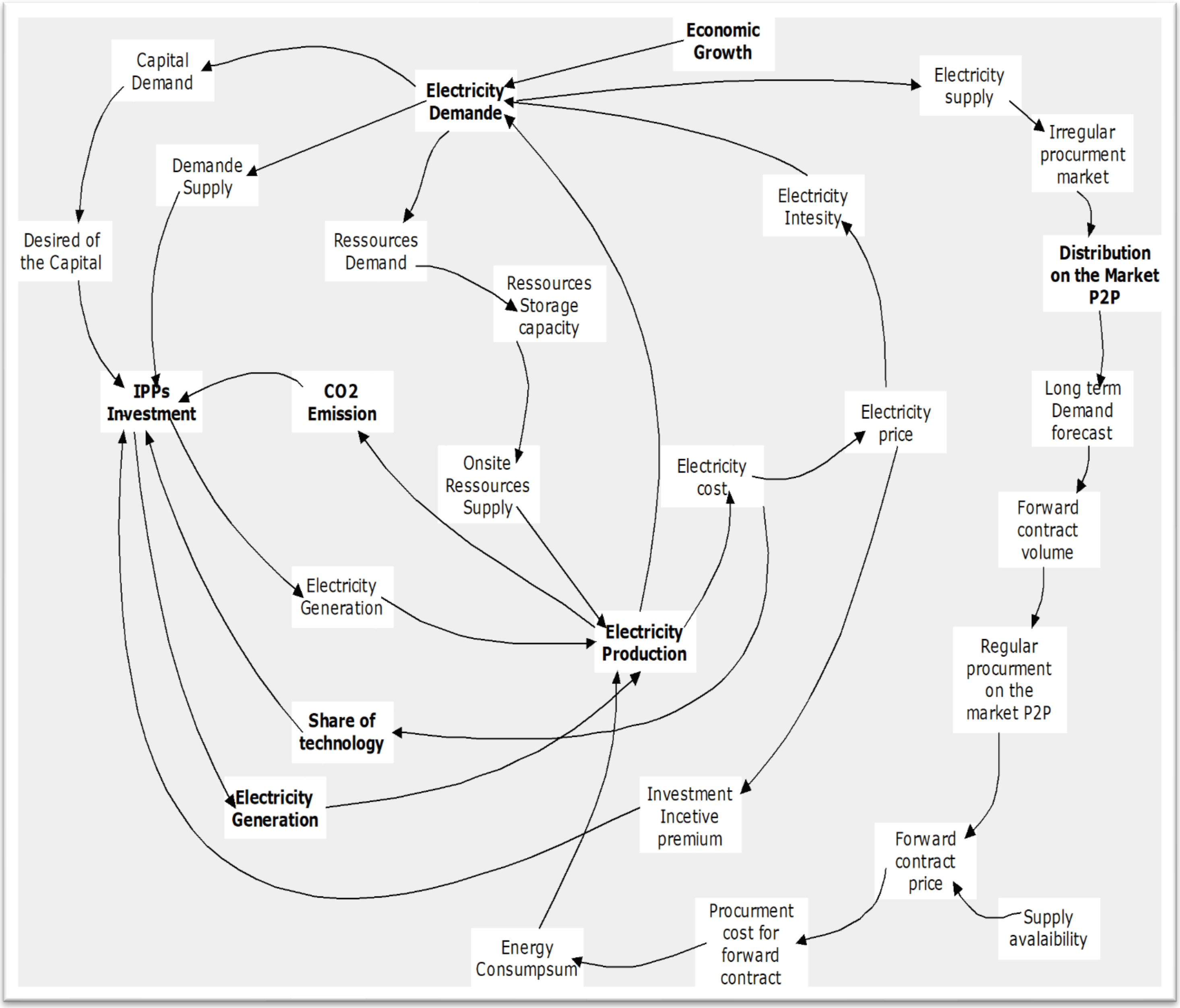


Figure 44:The conceptual model of MDESMP2P.

VI. CONCLUSION AND RECOMMANDATION

VI.1 Conclusion of the funding

This study also led to the implementation of digital technology in the mini-grid sector, more precisely research which followed on the study of the political and regulatory framework.

Thus, a more in-depth study on the assessments of the potential economic and social impacts of P2P energy exchange using blockchain using blockchain has been carried out; with the economic potential in the western part of Algeria and with all social and environmental living conditions which leads us to verify the feasibility of this project in Africa especially in the case study "Sidi Bel Labes". The construction of the dynamic system model of electricity and its design for the P2P energy trade based on the blockchain which models the phenomenon of the energy situation from a data collection but also a political incentive factor to be feasible and effective.

The literature review part allows us to give some notions on digitization for access to energy in sub-Saharan Africa, socio-economic and technological development which says a lot about the sharing economy, its functionality and its advantage about of the company, in this section we also talk about the development of blockchain technology, its process of exchange between stakeholders until the validation of the offer. Then Finally, this chapter contains the technical aspect of the implementation of P2P and blockchain energy trading. Finally, the current scenario on the energy market to be developed in order to know the functioning and shape of the energy market. Algeria is the choice of study with its energy policy effort for the fight against climate change. In addition, 98% of the population in Algeria is electrified towards the use of fossil energy, it is therefore a big challenge in Algeria this energy digitization project which brings an effect towards the climate. We have also noticed that this project can be carried out well by substituting with the projects that are already installed.

The methodology is based on the durability of variables interconnected with each other that are specific to the model of the dynamic system. The results are aimed at improving the field of electricity which has a positive effect on the development of overall economy. Collecting data from Households is an effective means of corroborating and validating information, taking into account the response of global stakeholders in the implementation. The study is designed to lay durability on empirical analysis, starting data collection and continuing to lay down an appropriate model and test that verifies the result obtained. Taking all of these results together guided us for a deeper evaluation with a meaningful conclusion.

Regarding community engagement, in the event that consumers realize a surplus of electricity, they become prosumers and will inevitably increase the users of the P2P system with their engagement.

Between the choice of green energy and the P2P system, the participants of this survey chose the P2P system in the reason that the functionality ensures their security with the advantage of production and sharing in all security. It also allows users transparency on the transaction and all internal procedures. In addition, the new technology allows to eliminate social distinction, on the other hand strengthens the global community in social terms. The companies have advantages for the marketing of their products and the outcome is almost assured.

In economic terms, the P2P system is advantageous on the possibility of the reduction of the price of electricity which leads to the improvement of the income of each household, the more the monetary flow which circulates on the economic circuit, the more the economic growth increases.

The MDESMP2P model was developed with the dynamics of the sectors of electricity demand, environment, production, price of electricity, investment and the P2P energy system market. It also captures the impacts of political incentives and pricing of electricity and capital-interest-based technology. Finally, the validity of this model will be tested on the comparison between the simulation of the model and the historical data.

VI.2 Recommendations

- The case of political incentive, investment in technology is the key to strengthening all activities that result in quality of service on electricity. Thus, the government should be looking for a way to strengthen a massive investment in this sector. In addition, encourage policy towards project competition linked to the use of renewable energy to attract local and international investment to invest.

- Exploitation in the use of production based on renewable energy can be carried out to encourage energy policy. In this case, the environment is better protected with a reduction in greenhouse gas emissions. The reduction of CO2 is possible by exploiting the electricity sector which has been shown according to the objective of the model. The economy becomes stable with a huge availability of electricity supply by reducing the use of fossil energy.
- The evolution of technology is leading us to the transition from energy sharing to Digitalization. The weakness of the central electricity distribution presents a difficulty from production to transmission to consumers. The political incentives have raised awareness for the production of energy based on the sun and to let people free to substitute their sources of energy in per-to-per-energy trading.
- The policy encourages the transformation of energy consumers into a producer and sell it in a P2P system market platform. This principle increases the purchasing power of each Household, in addition facilitates the transfer between the stakeholders without Intermediary.
- In order to have a very powerful energy policy, and to allow consumers to produce and sell it on the P2P energy system market, this analysis suggests a political intervention on economic recovery through long-term investment from the Algerian government. in this domain.

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Questionnaire Interviews questions

This part for the institutions and the general concerned bodies for the technical information and data of the electricity sector in Algeria.

1- What are the main sources of electricity generation?
2- What is the exact installed capacity of electricity generation for Khartoum, when and by whom?
3- What is the portion of electricity sources in the city?
4- Is there a national energy plan or long-term development plan?
5- How the increasing in oil prices affecting the electricity price and are there subsides?
6- How the general demand recorded and in which time scale?
7- What is the last 10 years' electricity demand percentage?
8- What are the challenges that facing the stable supply for the city?
9- What are the critical factors that have direct impact on the electricity supply?
10- What is the short term/long term road map of the electricity?
11- What is the level of community participation in the electrification action projects?
12- Is there already a Blockchain per-to-per Energy trading technology project here in Algeria? Otherwise: What are the barriers preventing implementation?
13- Is the State ready for the subsidy of this per-to-per energies trading energy digitization project?

To what extent does a social and economic policies impact the country? Questionnaire for the Community of Sidi Bel Labes, the survey covered the people who live in this willay, which means is considering the center of the capital and its neighborhood as extended areas around the city.

1- What is the number of your family members?
2- Do you have the following: Air conditioner, fridge, TV, microwave, fan, ….?
3- For how many years you connected to the national grid?
4- Where are you living, center of the city/country side?
5- How often the electricity goes off?
6- What is your average per capita income?
7- Does the electricity price affordable for you and how much is it?
8- Do you own a genet? solar panel? or SHS?
9- Did you buy it in a lone?
10- Does your job/work/activity need electricity?
11- What are the challenges that you have faced as a result of electricity cuts off or any economic loss than you had experienced?
12- To what extend does the electricity issue affect your social activities or did you miss any important interaction?

13- Do you know what the Green Energy term stand for?
14- Are you willing to have electricity from green resources and carbon free?
15- Are you willing to pay higher price for green electricity?
16- Do you know of manipulating computer technology?
17- What technology do you use to communicate and have information?
18- Preference between green energy and fossil energy?
19- Preference between P2P system and traditional energy company?
20- The goal of using this new technology P2P: increase the income vs contribute to fuel poverty?
21- Choice between trading, individual or in group?
22- Do you agree to connect with a new technology per-to-per energies trading in a platform to make an energy trading of blockchain per-to-per technology? If not, why?