Simulation of a Photovoltaic Panels Market for Promoting Solar Energy in Chad

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Abstract-Market research is an essential step for investment in the field of renewable energy. Chad is a country with significant solar energy potential which we study in the paper. Our study is based on the quintile of the population's well-being based on the incomes of five household categories to determine the number of solar panels that a Chadian household is able to pay. The aim is to demonstrate the existence of a potential solar energy market in Chad, to attract investments in the field of renewable energy to increase their share in the energy balance of the country. We evaluate the demand of the national photovoltaic solar panels market in order to satisfy the electrical needs of the population. The study found that by setting up the UPASE (Unit of Production and Assembly of Solar Equipment), we can have a cost of transfer to users of a solar panel of 200 Wp around 40,000 FCFA (67 USD), which is very competitive compared to the current selling costs which varies between 100,000 FCFA (167 USD) and 150,000 FCFA (250 USD).

Keywords: renewable energy promotion, solar energy, photovoltaic panels, market, Chad.

1. Introduction

One of the major challenges of the world today is climate change including the reduction of greenhouse gas emissions in terms of energy production and consumption, which account for about 80% of these emissions are caused by the use of fossil energies [1],[2]. The use of electricity from renewable sources is one of the solutions to mitigate this phenomenon of global warming [3], [4]. Solar energy is particularly adaptable to meet the energy needs of households or villages in local or isolated networks. The International Energy Agency reported in the 2018 that, solar photovoltaic covers 2% of global electricity production, which around 460 TWh, according to the International Energy Agency (IEA) in 2018 [5]. Frankfort School of Finance & Management and (UNEP) reports, the investments in solar photovoltaic reached a total amount of 280 billion USD in 2018 [6]. In fact, several countries have adopted policies to encourage the emergence of markets dedicated to renewable energies such as solar panels, as is the case in China, Europe, the USA, etc.[7].

An energy policy promoting renewable energies must have four objectives: (1) annual reduction of greenhouse gas emissions, (2) change in electricity demand, (3) change in the number of jobs in the electricity sector and (4) increase in the share of green electricity [8]. An instrument for the promotion of renewable energy must have a sufficient duration, for example 10 years [9].

In Chad, the electric power sector remains highly dependent on fossil fuels[10],[11],[12]; the country's energy balance is as follows: 96.5% of wood fuels, 3% of petroleum products and only 0.5% of electricity [13]. However, Chad has significant potential in renewable energies, especially solar energy as discussed in [14]. As part of Chad's vision of the emergence, the Government aims to increase the access rate to energy from 6.4% to 30%, whose share of renewable energy from 2% at the moment to 25% by 2030 [15]. To achieve this goal, substantial investments

and a sustained energy policy must be made to boost this sector.

In this regard, this article examines the different mechanisms for developing electricity from renewable sources. Our problem is to know:

• What are the modes of promotion of renewable energies in the world?

• What feedback from different mechanisms in the development of renewable electricity?

• How to finance the photovoltaic solar panels market?

To answer these questions, our article focuses in the context of Chad, a country with significant potential in solar photovoltaic energy, to identify market opportunities in photovoltaic solar panels.

Our work is structured as follows: Part 1 describes the mechanisms for promoting renewable energies practiced in the world. Part 2 compares the main modes of promotion by price or quantity. Part 3 evaluates the national demand for photovoltaic panels in Chad. Finally, Part 4 presents the simulation results of a photovoltaic panel market in Chad.

2.1. Mechanisms for promoting renewable energy

There are several mechanisms in the literature promoting renewable energies. We first distinguish two major categories of mechanisms based on their nature: direct and indirect instruments [16].

A support mechanism is defined as "a means of action chosen by policy makers to modify the behavior of the actors concerned in order to achieve the objective pursued". Direct instruments internationalize the positive aspects of renewable energies themselves. Meanwhile, indirect instruments externalize the negative aspects of other forms of energy, namely fossils.

There has been a variety of support mechanisms for renewable energy over the last 20 years.

Another classification consists of classifying support instruments according to government intervention into three categories: regulatory instruments, voluntary instruments and economic instruments:

- **Regulatory instruments** are institutional measures' aimed at constraining the behavior of polluters under penalty of sanctions administrative or judicial"[17]. These are emission standards, technology standards or product standards but also operating licenses. Voluntary approaches also require the introduction of renewable electricity certification rules, allowing a company to enhance its environmental performance and households to prefer consumption with less impact on the environment (system green pricing).
- **Economic instruments** more recent than regulatory instruments and more used than voluntary approaches, take the form of financial incentives along the entire renewable energy development chain: Research & Development, Investment, Production and Consumption.

Table1. Categorization of the main direct support instruments for renewable energy
(Source : Van Djik et al. 2003)

	Economic Instruments	Regulatory Instruments and Voluntary Instruments
R & D	- Fixed subsidies to R & D -subsidies for demonstration, test, development, etc. - low interest loans	
Investment	- Fixed Investment Subsidies - calls for tenders for investment grants - accelerated depreciation - tax reduction for investments in renewable energy - Agreements	negotiated between producers and government
Production	- Guaranteed purchase rates - calls for tenders - Reduction of taxes on income generated by renewable energy	- Quota of compulsory production -tariff or green marketing programs
Consumption	- tax reduction on consumption of renewable energy	- quota of compulsory consumption

Initially, the question of the integration of Renewable Energies is fundamentally technical as it concerns with the management of the power grid, but it is also of interest to economists since the question of cost arises in so far as the production objectives become more and more ambitious [18],[19].

2.1.1. The instruments "price" and the instruments "quantities"

Two large classes of instruments are classically mobilized to stimulate this development: the "price" instruments and the "quantity" instruments. The former associate purchase obligation and guaranteed prices (used in particular in Germany or France) and are generally considered to be the most efficient. The second rely on quantitative objectives (quotas) and flexibility mechanisms (green certificates or guarantees of origin). They are gaining increasing attention because they theoretically have better economic efficiency, and because they promote integration into the electricity market.

In the price system, the tariff is politically determined and the market sets the megawatt per hour quantities to be installed. On the other hand, the quantity of Megawatt (MW) is politically determined and the market determines the price in the quota system. Pricing approaches provide producers with more favorable economic conditions, and quantity approaches provide better control over capacity growth, and thus the associated costs [20].

2.1.2. Tariff systems

2.1.2.1. Guaranteed purchase rates (feed-in tariffs)

Guaranteed purchase tariffs or feed-in tariffs, consists of "imposing on electricity companies the purchase of electricity produced by renewable electricity producers located in their service area at a fixed, imposed rate by the public authorities, and guaranteed for a certain period (generally around 15 years). It includes three crucial provisions namely:

- A guarantee of access to the network;
- A long-term contract for electricity produced (15 to 20 years);
- A cost of repurchasing electricity based on changes in the cost of production.

This guaranteed purchase system has advantages, but also disadvantages.

a) Advantages:

- Low market risk for the investor with income independent of fluctuations in the price of conventional electricity in the market;
- Incentive to progress with an investment in R & D to develop high-performance technologies to reduce the cost of production;
- Transparency in access to information on the purchase price, which does not present a transaction cost to the investor.

b) Disadvantages:

- For public authorities, no guarantee a priori on the quantitative objective in terms of installed capacity;
- Difficulty in establishing tariff digression over time, taking into account technical progress, to ensure a balance of the marginal cost of certain producers, significantly lower than the purchase price;
- High cost of the system for the end consumer, by the extra cost of operators to fulfill their public service mission.

Rates are made to encourage lower cost of production. They must be different depending on the source, the size of the project and its location, in order to diversify renewable energy sources by guaranteeing investors a return on investment. It is the system in force in more than 50 countries in the world including Algeria, Belgium, France, Germany, etc. Germany, Spain and Denmark alone account for more than three-quarters of installed wind power in Europe.

2.1.3. Quota systems

2.1.3.1. (Bidding procedures) in the competitive tendering

In the bidding system, the State, the authority responsible for the purchase of electricity or the electricity supplier issues a call for proposals (Request for Proposal) for the supply of a quantity of electricity of renewable origin with obligation of purchase, by the network of the production of the selected operators. Operators compete in auctions for fixed-price contracts during auction rounds. Bidding is used in England under the Non-Fossil Fuel Obligation (NFFO) program, launched in all renewable energies, in Ireland and Scotland, and also in France with the program "Éole 2005" concerning the development of wind energy.

a) Advantages:

- Control of the quantity of green electricity to be installed by the power plants
- Choice of regions to implement the capacities to install allowing the public authorities to carry out a spatial planning policy. which is not the case with guaranteed purchase tariff systems;
- No additional cost (differential rent) for the end-user since the bid prices should therefore be in line with the marginal costs of bidders, adding a reasonable profit. For example, the program "Éole 2005" in France gave an average wind power purchase price of 47.5 Euros per MWh against 80 Euros for guaranteed purchase tariff systems.

b) Disadvantages:

- Uncertainty on bidders' calls and bid costs, thus the guarantee on the achievement of objectives on the quantities to be installed despite the competition;
- High transaction costs due to the procedure to be followed during the offer (drafting of specifications, information of the suppliers, etc.);
- Low incentive for producers to research and develop, which lowers the cost of production by lower wages, than in FIT systems.

2.1.3.2. Green certificates or tradable quotas

Green certificates are securities that play the role of a bonus given to the production of green electricity. These are mandatory renewable electricity production quotas imposed on operators operating on the market. These operators can meet these obligations in three ways: either by producing themselves the green electricity imposed by the authorities; or by purchasing it from another producer via long-term supply contracts; or by acquiring certificates corresponding to the amount of green electricity needed to meet the quota in a financial market.

These mechanisms are negotiable on the securities markets in Europe since the 2003 European Directive (in England, Belgium and Italy). They made their first

appearance in the early 90's in California (USA). These systems are not conceivable in Chad because of the lack of interconnection between the financial markets.

2.2. Comparison of economic instruments

The comparison of these different support mechanisms on the basis of their intrinsic functioning is not sufficient and it does not release any instrument to favor at the expense of others. In addition to their economic efficiency, it will be necessary to define other types of criteria: environmental efficiency, transactional efficiency and dynamic efficiency of these mechanisms.

Table2. Summary of the effectiveness of renewable energy support modes

	Guaranteed Purchase Rates	Calls offers	Certificates green
Respect of the "quantity" objective	-	++	++ - (if penalty)
Minimizing the cost of achieving the goal	-	+	++
Incentive to lower costs	-	++	++
Producer-buyer transaction costs	++	- -	- (spot market) (long-term contracts) ++ (vertical integration)
Predictability / stability of the regulatory contract	++	-	-
Ability to innovate (R & D)	++	-	-

Guaranteed purchase rates have average results in terms of environmental efficiency and do not ensure that the quantitative objective set by the policy is achieved ex ante. In terms of static economic efficiency, Feed In Tariffs have relatively low implementation and administration costs, and allow de facto differentiation according to the level of maturity of the value chains without presenting an additional administrative cost. On the other hand, these systems do not control the differential rent of the producers and therefore of the total cost. Finally, guaranteed purchase tariffs provide a stable framework for innovation with regard to the ability to stimulate a dynamic of technical progress but have a lower incentive to lower costs than the other two instruments.

The calls for tenders certainly make it possible to reach the quantitative objective targeted by the programming of the auction rounds as well as the distribution of the production facilities from resources according to the potential of the territory (better environmental efficiency). As far as economic efficiency is concerned, they show better controllability of the producers' differential rent and a differentiation of the level of support and the nature of the technologies in the calls for tenders. Finally, competitive bidding contributes to lower production costs by directly competing producers for their dynamic efficiency, but they exert only a small incentive to innovate by virtually canceling the technological rent of the producer's innovative developers thus reducing R&D expenses and therefore the cost.

Green certificates rely on mechanisms to plan the achievement of environmental policies for renewable energy development over time. In terms of economic efficiency, they allow equalization of the marginal costs of production with efficiency in the allocation of resources. Finally, exchangeable quotas give investors little predictability. However, they grant a low technology rent to innovative developers.

At the end of this comparative analysis, no single instrument can bring together the characteristics necessary for effective promotion of renewable energies. Therefore, these policies need to be accompanied by complementary measures, including R & D, investment and consumption subsidies [21]

3. Methodology

In Chad, the renewable energy market is embryonic. To boost this sector, investments in this area are necessary [22]. Given the country's significant solar potential, investments in solar photovoltaic energy are crucial [23]. Hence our methodological approach which consists of simulating a solar panels market study in Chad. This is based on an estimate of the demand for photovoltaic solar panels and the assessment of the turnover that this market could generate annually by the sale of these products by a unit of production and assembly of solar equipment (UPASE).

3.1. Methodology for quantifying the demand of solvent households

Quantification of demand is estimated by the ability of solvent households to afford solar equipment to meet their basic energy needs.

According to the statistical results of the General Census of Population and Housing (RGPH2), the Chadian population is estimated at 12 million inhabitants, whose number of persons per household is 6 persons [24].

By reporting the total population of the country on the number of persons per household, we obtain about 2 million, which will serve as a basis of calculation as the total number of households in Chad.

According to these results, Chadian households are divided into five categories in equal proportion (20% per category), for their social welfare.

Table3. Quintiles of well-being

Well-being level	Number of households	Average expenditure per capita per year	Share of expenditure in electricity by household
Poorer	400,000	66,321 FCFA[1]	5.2
Middle poor	400,000	120,634FCFA	6
Median	400,000	233,661FCFA	5.2
Middle rich	400 000	295 872FCFA	5.6
Richer	400,000	617,292FCFA	5.4

3.2. Evaluation of the national market in solar photovoltaic panels

The purpose of the market assessment is to determine the number of solar panels that can be purchased by solvent households at reasonable prices. Compared to the 5 categories of households, we will make our evaluation with 50% of four categories (average poor, median, middle rich and richest) while excluding the poorest households.

4. Results and discussions

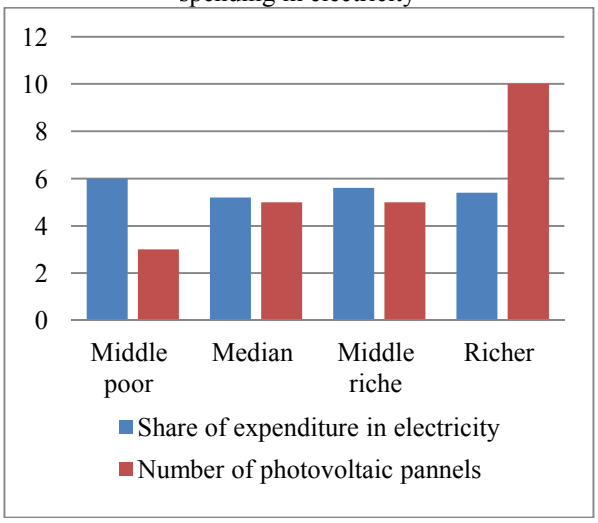
For the four mentioned other categories of households, we calculated the number of solar panels units according to the following hypotheses:

- 50% of the "richer" household category can buy 10 panels annually;
- 50% of the middle-rich household category can buy 5 panels per year;
- 50% of the "median" household category can subscribe annually to 5 panels;
- 50% of the "poor middle class" households can subscribe annually to 3 panels.

According to the share of their expenses in electricity, the calculation of number of the panels units gave us the following results:

- 50% of the "richer" household category can buy 2,000,000 units;
- 50% of the middle-rich household category can buy 1,000,000 units;
- 50% of the "median" household category can subscribe for 1,000,000 units;
- 50% of the "poor middle class" households can subscribe 600,000 units.

Fig.1. Number of solar panels based on household spending in electricity



The calculation of the solvency demand in solar photovoltaic electricity, limited to that of solar panels, is made on the basis of the elements considered above, especially the sale price of the panel stopped at 39,600 FCFA instead of 75,000 FCFA, practiced by importer.

It should be noted that this is an annual average that will be fed by several contributions that are among others:

- The reserve of 800,000 solvent households;
- The annual constitution of new households or families;
- The transition from some lower-class households through their income to a higher category.

To this household market, it will be necessary to add that of the projects, financed by the Government and the development partners, in the field of rural electrification (pumping of water, conservation of medicines, etc.) and urban through public lighting, urban centers, which can be estimated at a flat rate of 2,000,000 units.

By adding all the offers of panels expressed, having to answer various requests, we arrive at a total of almost 8,000,000 units each year. This confirms the existence of at least a solvent demand for the order of 5,000,000 panel units each year to satisfy Chad, through a consistent and competitive offer as described above.

We can extrapolate the total profit margin generated annually through the sale of 5,000,000 panels with a profit of 3,600 FCFA per unit. Which gives us: 5,000,000 x 3,600 = 18,000,000,000 FCFA.

Even on the basis of a pessimistic estimate, the other accessories needed for the production of solar photovoltaic electricity could generate a total profit of at least 735 billion FCFA or more. This is the cost price plus a profit margin. For ease of calculation, we have rounded this sale price to 40,000 FCFA.

[1] Central African CFA Franc currency

Table4. Selling price, cost price and profit margins

Type of equipment	Unit price (FCFA)	Cost price	Profit margin	Margin in%
Photovoltaic panel 100 Wp	75,000	30,000	45,000	150%
Battery 100 W	65,000	32,500	32,500	100%
Converter 1000 W	50,000	30,000	20,000	66.7%
Converter 2000 W	100,000	55,000	45,000	81.8%
Converter 3000 W	135,000	90,000	45 000	50%
Regulator 10 A	35,000	15,000	20,000	57%
Regulator 20 A	60,000	20,000	40,000	66.6%
Regulator 30 A	75,000	27,500	47,500	62.6%
Lamp 3 W	500	200	300	150%
Lamp 5 W	750	300	450	150%
Lamp 8 W	1,250	400	850	212.5%

Fig.2. Total expenditures based on total solar panel

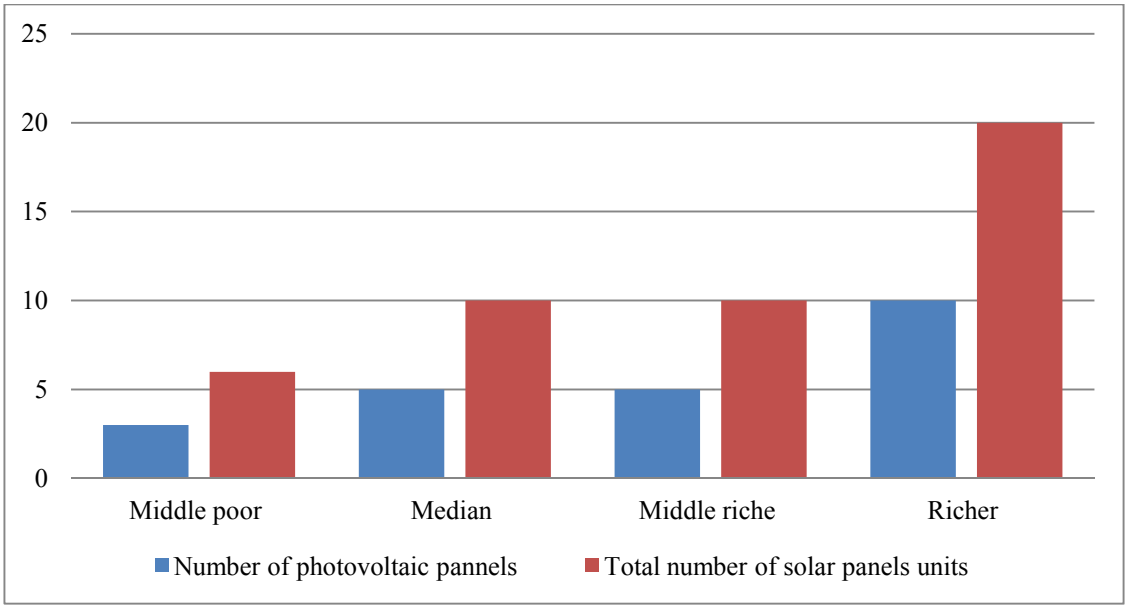


Table5. Ex-works price (UPAES), profit margin and user selling price

Type of equipment	Cost price from China	Price released UPAES	Profit margins to share	User selling price
Photovoltaic panel 200 Wp	30,000	36,000	3,600	39,600
Battery 100 Ah	32,500	38,400	3,840	42,240
Converter 1000 W	30,000	36,000	3,600	39,600
Converter 2000 W	55,000	66,000	6,600	72,600
Converter 3000 W	90,000	108,000	10,800	118,800
Regulator 10 A	10,000	12,000	1,200	13,200
Regulator 20 A	15,000	18,000	1,800	19,800
Regulator 30 A	22,500	27,000	2,700	29,700
Lamp 3 W	200	200	200	400
Lamp 5 W	300	300	300	600
Lamp 8 W	300	300	300	600

Table 6. Type of solar kits selected for market simulation

Type of equipment	200 Wp kit	Unit price in FCFA	Unit price in USD	Quantity	Total price in FCFA	Total price in USD
Photovoltaic panel	200 Wp	40,000	67	5,000,000	200,000,000,000	333,333,333
Battery	100 Ah	42,000	70	5,000,000	210,000,000,000	350,000,000
Regulator	20 A	20,000	33	5,000,000	100,000,000,000	166,666,666
Converter	1 000 W	40,000	67	5,000,000	200,000,000,000	333,333,333
Cable	20 m	40,000	67	5,000,000	200,000,000,000	333,333,333
Lamp	5W x 8	5,000	8	5,000,000	25,000,000,000	41,666,666
Total		187,000	312	5,000,000	935,000,000,000	1,558,333,333

5. Conclusion

The extrapolation of this buoyant market for the manufacture of solar panels locally, carries with it the existence of a market for all solar equipment. To meet this demand, it is imperative to set up a Unit for Production and Assembly of Solar Equipment (UPASE). In Chad where our study may be serve as a basis for its technical feasibility and financial viability. The search for a solution to the energy equation as described above led us to propose the operation of the UPASE.

The technical and financial feasibility of setting up the production unit is unambiguous. The main parameters of this feasibility, in particular the existence of a market potential, which is important in terms of size, which must justify the investment and the return on investment, has been demonstrated sufficiently above. Similarly, the commitment of the State to honor its counterpart in terms of regulatory and fiscal reform incentive to the establishment of the Unit is not an insurmountable problem.

In terms of financial profitability, we believe that it is noticeable without counting other benefits, including environmental benefits, poverty reduction, job creation, food security and others.

Thus, all the elements of economic and financial analysis referred above, provide ample evidence that the setting up of a UPAES, may be feasible and very profitable.

The evaluation of the annual turnover just for the panels gives us: by multiplying the size of the annual market which is 5,000,000 panels by the unit selling price which is 40,000 F CFA (including the profit margin to share between the production unit, wholesalers and retailers), we may have 200 billion FCFA of turnover. By adding 735 billion for other accessories, we then reach a total of 935 billion FCFA turnovers.

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