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## Article

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# Energy Transition from Fossil to Renewable Sources in North Africa: Focus on the Renewable Electricity Generation in Morocco

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## ABSTRACT

The aim of this article is to study the context and the challenges of the North African region in its quest towards energy transition. This work performs firstly a benchmark between the countries namely Algeria, Egypt, Morocco, and Tunisia, in terms of fossil resources and renewable potential based on official data and statistics. The study then focuses on Morocco, who is developing a new energy transition model axed on renewable electricity generation. In order to highlight the importance of legislation and economic evolution, the study compares the high with medium voltage renewable electricity market. In fact, a framework law has been established allowing private investors to benefit from the national electricity grid to inject and sell high voltage renewable electricity. Not being the case for medium voltage, the electricity transition for this market is depending on its own business model and economic profitability, therefore, a financial profitability study is further conducted to evaluate medium voltage photovoltaic competitiveness. The study concludes with the profitability impact assessment if 50% of the investment amount is subsidized by state or any other organization. The results of this study are discussed considering the current legislative context, it demonstrates the importance of subsidies and state legislation to accelerate the energy transition towards renewable energy development.

**Keywords:** Renewable Energy Sources, Photovoltaic Electricity, Electricity Transition, Profitability, Cash Flow, Payback, Subsidies

**JEL Classifications:** Q4, Q5, K2

## 1. INTRODUCTION

In addition to fossil resources, the countries of north Africa have very favorable geographical conditions for renewable energy development (Nathaniel et al., 2020), and like the rest of the world, this region has already faced the effects of climate change. Therefore, there is an increasingly urgent need to reduce greenhouse emissions and encourage measures for an adequate transition to renewable resources. The establishment of a transition policy is challenging for the region. Namely Egypt, Algeria, Tunisia and Morocco, each country must face, often alone, its own energy context. The ambition to introduce renewable energy is depending on many considerations such as economic profitability and a favorable legislative context

(Constantinidou et al., 2019) yet it is motivated by sustainable development and environmental protection.

Renewable energy awareness has gained interest with different ambitions across north Africa, the focus is mainly on solar and wind energy (Avis, 2020) which can offer huge development alternatives for electricity production. Morocco is well engaged in renewable energies thanks to the national strategy and the locally developed expertise of the national and international operators (Moroccan environmental council, 2020). At present, lower cost of photovoltaic panels is one of the important factors that have made it possible to ensure its profitability (EIA, 2020) however, in the absence of price regulations, the profitability remains of

paramount importance for a successful energy transition lead by the private investors.

## 2. CHARACTERISTICS OF THE NORTH AFRICAN ENERGY MARKET

### 2.1. Dependence on Fossil Fuels

Security and access to a reliable source of energy is fundamental in order to meet the economic and social needs of any society. As for North Africa, the region is particularly rich in fossil resources, but suffers a lack in electricity access for all (European Commission, 2019; EIA, 2020). This gap is due to insufficient infrastructure, which most countries are trying to make up for by massive investment programs in fossil and renewable energy. However, Although the geographical similarities in this region, the energy context remains very different from one country to another, the Table 1 shows the disparities in oil reserves capacities.

The data shows that Algeria is by far the country with most fossil resources in the region, followed by Egypt which has more natural gas resources than crude oil. Morocco and Tunisia are last with very little reserves. Therefore, the gap between these countries' fossil resources is very considerable, which naturally affects the dependency level on petroleum products, and naturally, influences the energy strategy.

The diversity of north Africa countries in terms of energy mix and fuel infrastructural development can also be observed in the energy projects deployed. For example, the number of local refineries is a fundamental indicator that reflects the importance of oil industry. The uneven distribution of proven oil and gas reserves accentuates the concentration of refineries in Algeria and Egypt comparing to Morocco and Tunisia, as shown in the Table 2.

It is with no surprise that Algeria and Egypt, the two countries with most oil resources in the region, also have the largest number of refineries on their soil. The natural gas, of which Algeria is one of the main producers and exporters in the Middle East and North Africa (MENA) Region (Menara Working Paper, 2018). According to the International Energy Agency (IEA), Algeria exported nearly 580,000 barrels per day of crude oil and condensate in 2017 (EIA, 2017), its energy policy is still heavily relying on fossil fuels.

On the other hand, Morocco and Tunisia are the two countries of North Africa having the least petroleum resources. Given the fact that more than 90% of its electricity come from gas imports (IEA, 2018), the Tunisian energy policy is more focused on renewable energy development. Regarding Morocco, fossil fuels account for 68% of its installed energy capacity (RCREEE, 2020). The country is seeking to meet its growing energy demand by developing renewable energy potential, a goal has been set to reach 52% of electricity produced from renewable resources by 2030, focusing mostly on solar and wind energy (RCREEE, 2020).

### 2.2. Strategic Orientations Towards Renewable Energies

Between the pollution generated by fossil energies, and the imports dependency due to the lack of oil reserves, Morocco and Tunisia have drawn up a new energy strategy, the main objective is to introduce renewable energies into the energy mix. This strategy is encouraged by their renewable energy potential (IRENA, 2014). As shown on the Tables 3 and 4, north Africa is very rich on renewable energy resources.

The data shows that north Africa countries have the potential to build an energy model based on ecological development; but for

**Table 1: Fossil fuels reserves in North Africa countries (Algeria, Egypt, Morocco and Tunisia) in 2017 and 2019**

Country	Total recoverable coal (million tons) in 2017	Crude oil proved reserves (billion barrels) in 2019	Natural gas proved reserves (trillion cubic feet) in 2019
Algeria	65.04	12.2	159.05
Egypt	17.67	3.3	63
Morocco	15.43	0.00068	0.05
Tunisia	-	0.43	2.3

Source: Energy projections for African countries, Joint Research Centre (JRC), Technical Report, 2019

**Table 2: List of existing oil refinery by country**

Country	Refinery	Owner	Distillation capacity (Kb/d)
Algeria	Adrar	CNPC/Sonatrach	13
	Algiers	Sonatrach	58
	Arzew	Sonatrach	90
	Hassi Messaoud	Sonatrach	27
	Skikda	Sonatrach	462
Egypt	Alexandria (Ameriya)	EGPC	88
	Alexandria (El Mex)	EGPC	115
	Alexandria (MIDOR)	EGPC	115
	Assiut	EGPC	60
	El Suez	EGPC	68
	Mostorod	EGPC	145
	Nasr El Suez	EGPC	146
	Nasr Wadi Feran	EGPC	9
	Tanta	EGPC	54
Morocco	Mohammedia	SAMIR	200
Tunisia	Bizerte	Ste. Tunisienne	34

Source: Energy insights by McKinsey, 2020

**Table 3: Summary of renewable energy potentials in North Africa**

Region	Total area (km <sup>2</sup> )	CSP overall sum (Twh/year)	PV overall sum (Twh/year)	Wind overall sum (Twh/year)
Northern Africa	6,784,934	93,544	109,033	130,316

Source: The International Renewable Energy Agency (IRENA), Estimating the Renewable Energy Potential in Africa, 2014

**Table 4: Results by country for Photovoltaic (PV), Concentrated Solar Power (CSP) and wind energy**

Country name	Total area (km <sup>2</sup> )	CSP overall sum (Twh/year)	PV overall sum (Twh/year)	Wind overall sum (Twh/year)
Algeria	2,316,559	26,530	27,904	30,155
Egypt	982,446	26,605	32,218	36,601
Morocco	406,318	15,127	15,155	11,297
Tunisia	155,176	2045	4645	6842

Source: The International Renewable Energy Agency (IRENA), Estimating the Renewable Energy Potential in Africa, 2014. Photovoltaic (PV), Concentrated Solar Power (CSP)

this to be possible, considerable infrastructure investments are necessary. Given the significant potential of solar and wind energy, the countries can position themselves as leaders in this transition. In order to achieve this transition, energy efficiency must be established as a priority. New energy strategies should focus on a diversified and optimized energy mix, that must rally reliability and competitive technological choice. The latest IEA report on Clean Energy Transitions in North Africa, shows that electricity is the sector with the highest penetration potential of renewable energy, accounting for 6.9% of supply in 2018 (EIA, 2020).

Morocco has a leading position in the region, in terms of integrating renewables in the electricity generation (World Bank Group, 2018). In 2018, wind and solar energy became the first generating source in Morocco, renewable sources have reached out around 34% of total electricity installed capacity, the objective is to reach 50% by 2030 (The Moroccan Ministry of Energy, Mines and the Environment official Website). The rest of this study will focus on the electricity transition to renewable energies in Morocco.

### 2.3. Competitiveness Level of Renewable Energies

The current energy context is very favorable to the development of renewable electricity generation. This is mainly due to the development of new capacities and the increasingly confirmed competitiveness comparing to fossil electricity. The main factor is the declining cost for the newest wind and solar projects (EIA, 2020). According to Annual Energy Outlook 2020 Report, this trend is further confirmed for the next 10 years to come (EIA, 2020).

Photovoltaic solar (PV) has been attracting investors from all industry sectors, including oil and gas operators. Although the solar equipment providers and contractors were able to overcome the PV over-capacity crisis (Zhang et al., 2013), they have faced a very volatile market reacting to price and incentive variations. Concentrating Solar Power (CSP) projects are mostly growing in emerging countries especially Morocco and South Africa (IEA, 2020). Engineering Procurement and Construction (EPC) Contractors who propose their services in CSP technology are mostly turbines manufacturer and energy infrastructure giants who partner with solar energy companies and heat transport specialist. The CSP market shrinkage is attributed to a strong decrease of states' support combined with the collapsing cost of PV energy becoming more interesting for investors (McBride and Stettenheim, 2017). As for wind energy, this sector

is developing very quickly, efficiency is mainly depending on wind speed, grid connection, and wind turbine types (IRENA, 2016). Wind is most known to be a suitable renewable source for higher capacity projects comparing to solar energy (IRENA, 2016).

Many factors can influence renewable electricity generation, financial conditions and state incentives are considered fundamental drivers of cost-efficiency (Mezosi et al., 2018). Other factors can strongly influence production cost, the number of sunshine hours per year for PV and its distribution is a determining criterion, the objective is to reduce intermittence effect. Although "Smart Grids" have strengthened electricity production, the boom in solar electricity production is mainly due to the significant cost decline of PV panels (Green, 2019). The photovoltaic sector is growing potential is attracting new actors, who greatly benefits from decades of experience and expertise.

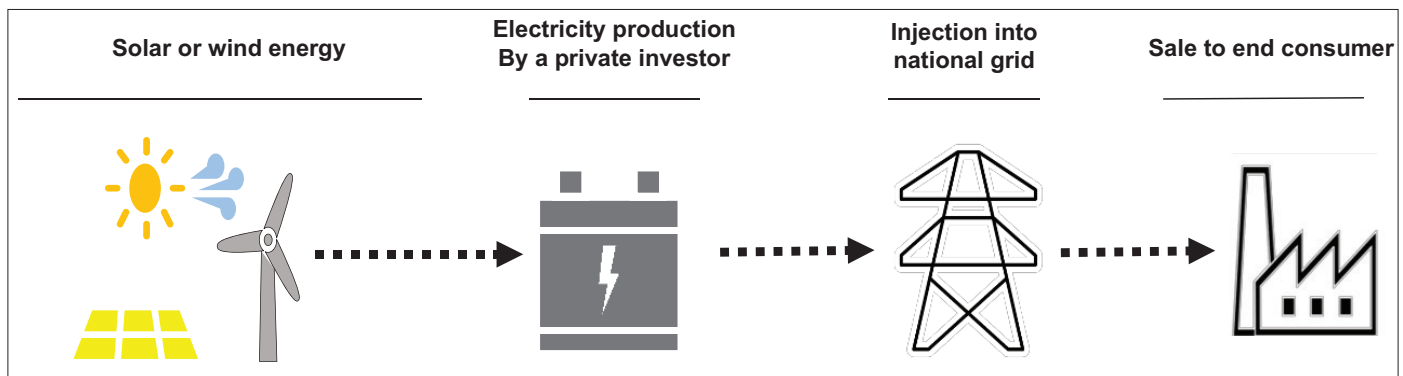
## 3. TRANSITION FACTORS FROM FOSSIL TO RENEWABLE ENERGY IN MOROCCO

### 3.1. Energy Policy and Legislation

The establishment of a clear policy to support the transition to renewable energy is proving to be a key element. In this perspective, Morocco had issued a law in 2010 (Ministry of energy Law 13-09, 2010) that offers the possibility for any private operator, to produce and inject electricity from any renewable source into the national grid, subject de certain conditions: it is necessary to follow an administrative process over several stages to obtain prior authorization, which is initially provisional, but becomes final at the end of the project. The technical and commercial connection conditions to national grid are negotiated. Only the high voltage network is concerned by this legislation, which limits beneficiaries only to important solar or wind capacities investors.

This law thus defined, gives the possibility to the big operators with important projects to sell green electricity to important consumers according to the scheme in Figure 1.

This favorable legislation has encouraged private investments on renewables, which leads to free competition and fast market development. While awaiting an amendment in order to integrate the medium voltage, the developments of this very demanding market

**Figure 1:** Production and sale Scheme of high voltage renewable electricity generation

remain challenging. In fact, the current law does not offer the possibility to inject medium and low electricity voltage into the national grid, which means that the electricity production must be done near the end customer for immediate use, any overproduction is assimilated to a loss in the absence of a practical energy storage solution.

Many challenges may arise, such as the need for a significant amount of investment or the distance disadvantage, the ideal geolocation for optimum production can be far away from the customer location, without any ideal solar exposure or wind speed necessary to produce optimum electricity.

### 3.2. Development of the Photovoltaic Electricity

In general, the higher the price of fossil electricity, the more conducive the environment is for the development of electricity from renewables. Thus, in a market open to competition and the absence of direct state subsidies for medium and high voltage, the business model is entirely capitalizing on cost reduction. Customer prospection relies on interesting economic offers, with an electricity price lower than the national operator.

The current legislation allows electricity production and sale but does not provide direct subsidies systematically (Law 13-09, 2010). As a result, this market has become very competitive and challenging for private operators, which has enabled Morocco to be among the cheapest electricity cost production in north Africa (Avis, 2020). The business model is based on a complete and integrated offer carried by the supplier, the electrical utility service providers intervene within the frame of competitive bidding, taking an integrated approach from site selection, procurement of equipment, financing, project planning and construction, to operations and maintenance.

Given the fact that PV panels are more adaptable than wind turbines in terms of installation in urban areas such as parking's, roofs, or adjoining lands; it is more suitable to develop PV over wind electricity for medium voltage consumers. For the PV electricity offer to be competitive, solar panels must comply with some electrical and mechanical characteristics:

- Efficiency per panel greater than or equal to 17% (Cui et al., 2019)
- An installation easily accessible for maintenance or control
- Mechanical stability of PV modules support on the ground and on the roofs
- Resistance to long-term corrosion.

The PV inverters must provide several functions and characteristics, such as a direct injection of PV electricity produced into the site's internal electricity grid, with the possibility of automatic triggering and switching on and off the installation. The PV installation should ensure a high degree of reliability and efficiency.

## 4. PROFITABILITY STUDY OF PHOTOVOLTAIC ELECTRICITY INTENDED FOR MEDIUM VOLTAGE CONSUMPTION

### 4.1. Business Model Structure

Some industries choose to show their sustainable commitment by investing in renewable energies, the objective is to be able to produce solar electricity in-situ (for self-consumption). The service provider offers a contract and business model scheme. The commonly adapted Formula is in the form of a Power Purchase Agreement (PPA) (Luther-Jones, 2019), which is an electric energy purchase contract, with terms between the seller and the buyer for providing electricity produced by a photovoltaic solar park, in return for a remuneration.

To ensure the viability of this business model, the selling price should not be indexed to actual costs, but rather fixed to be lower than the price of electricity supplied by the national operator, the discount becomes interesting for buyer starting from 10%.

A PPA must contain a remuneration scheme with a fixed electricity price over the duration of the contract, with a legal framework of the service, typology, liability, and insurance. The profitability study conducted is considering selling the self-produced electricity independently, without any possibility of injecting the surplus production into the national electricity grid. The scenario can be qualified as self-production regime.

### 4.2. Profitability Study

To conduct this profitability study, we took the case of a photovoltaic installation of 10 Wc capacity, the following assumptions are made base on official PV reports:

- The investment amount is : € 800/kWc (Energy Regulation Commission, 2019)
- Operating and maintenance cost of photovoltaic panels is:



0.053€/Kwc (Bennouna, 2020)

- The estimated efficiency drop in photovoltaic performance is: 0.35% per year (Grubišić-Čabo et al., 2020)
- The average rate of sunshine in Morocco is around: 5000 kWh/kWc/year (Renewable Energy Development Center, 2015)
- The PV inverters should be replaced every 10 or 12 years, with an estimated cost of 900 € (PV Panel Supplier Alma Solar Official Website).

In the photovoltaic market, two main families of modules are currently represented (Energy Regulation Commission, 2019): modules based on mono or polycrystalline silicon and thin film modules based on cadmium telluride. On one hand, the manufacturing process of thin film modules is faster and less expensive but with lower efficiency, on the other hand, the use of silicon gives a greater purification and therefore exhibit a better efficiency; reason why polycrystalline modules are chosen for this simulation, their average yield is estimated at 17.6% (Energy Regulation Commission, 2019).

For the simulated consumption bracket, the electricity tariff applied by the national distribution operator is 0.21 \$/Kwh (Moroccan national electricity Office). For a potential buyer to be interested in a renewable electricity supply, we assume that the rebate offered by the provider must not be <15%, on this basis, the sale price used for this simulation is 0.1265 €/Kwh.

**Table 5: Profitability simulation for 10 Wc PV installation**

Summary of the main assumptions	
Investment (€/KWc)	800
Operating Cost (€/KWc)	0.053
Drop in efficiency factor (%)	0.35%
Everage rate of sunshine (kWh/kWc/an)	5000
Average Yield (%)	17.60%
Tariff Applied (€/Kwh)	0.1785

In light of the above technical and economic assumptions, the profitability simulation for a photovoltaic installation of 10 Wc capacity is as follows in Table 5.

The generated annual cash flow represents approximately 13% of the investment, which in terms of the accumulated cash flow, will require 9 years to recover the initial investment amount and start generating profit Figure 2.

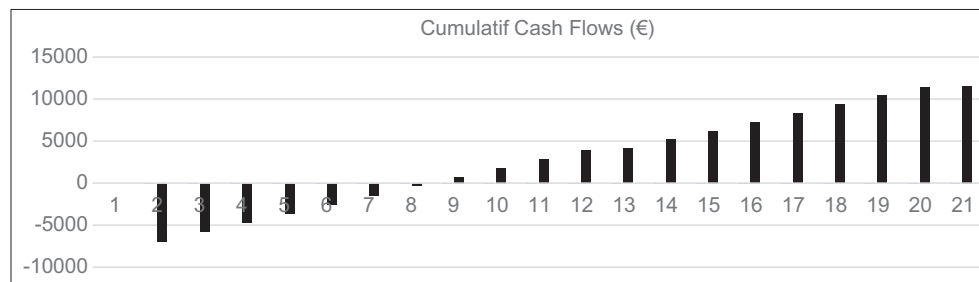
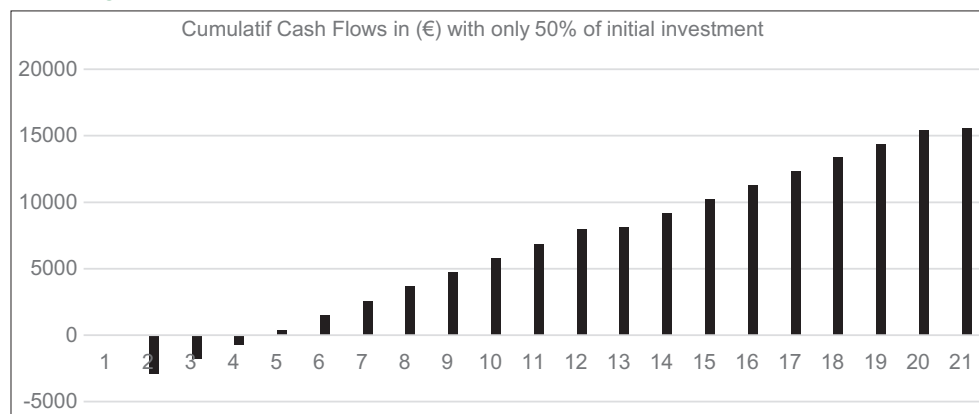
This simulation does not cover the type of investment financing, which can be partially or totally in the form of a bank loan. In this case, other financial costs relating to the interest rate and repayment of the loan will be added to the operational costs already considered. This can only delay the return-on-investment period and make it less attractive.

## 5. RESULTS ANALYSES

This study allows an evaluation of the profitability of PV electricity, in a legislative context that does not allow the injection of the surplus production into the national electricity grid. The current weakness of this business model is the electricity selling price structure, which is not indexed to real costs, this can lead to the sale at negative margins. The only pillar of optimization remains the reduction of photovoltaic panels and maintenance costs.

The financing or subsidy that can be granted by the State is a determining point for the development of the PV medium market. Currently, there are several international multilateral institutions present in Morocco and intended to support competitiveness and improve the sustainability of the sector. The Morocco Sustainable Energy Financing Facility program (MORSEFF, 2020) is a financing line developed by the European union, to promote investment in sustainable energy in Morocco. The financial subsidies offered by the MorSEFF can go up to 50% of the investment cost (Ministry of Energy, Directorate of Observation and Planning, 2018).

Year	Power installed (kWc)	Investment amount (€)	Average annual production (KWc)	Average cost of operation and maintenance (€)	Changing inverters	Annual turn over (€)	Net cash flow (€)	Cumulatif cash flow (€)
0	10	-8.000						
1			8.800	-466		1.571	1.104	-6.896
2			8.769	-465		1.565	1.101	-5.795
3			8.739	-463		1.560	1.097	-4.698
4			8.708	-462		1.554	1.093	-3.606
5			8.677	-460		1.549	1.089	-2.517
6			8.647	-458		1.544	1.085	-1.431
7			8.617	-457		1.538	1.081	-350
8			8.587	-455		1.533	1.078	728
9			8.557	-453		1.527	1.074	1.802
10			8.527	-452		1.522	1.070	2.872
11			8.497	-450		1.517	1.066	3.938
12			8.467	-449	-900	1.511	163	4.101
13			8.437	-447		1.506	1.059	5.160
14			8.408	-446		1.501	1.055	6.215
15			8.378	-444		1.496	1.051	7.266
16			8.349	-443		1.490	1.048	8.314
17			8.320	-441		1.485	1.044	9.358
18			8.291	-439		1.480	1.040	10.399
19			8.262	-438		1.475	1.037	11.436
20			8.233	-436	-900	1.470	133	11.569

**Figure 2:** Cash-Flow for 10 Wc PV installation**Figure 3:** Cash-Flow simulation for 10 Wc PV installation if 50% investment subsidies

Therefore, by reducing the investment amount by 50%, the cumulative cash flow of the same photovoltaic installation studied previously, and using the same assumptions, becomes as follows in Figure 3:

The new cash flow simulation shows a 5-year payback for 50% of the initial investment instead of 9 years for zero subsidies, which can significantly encourage the development of the PV Market.

## 6. CONCLUSION

Renewable energies are an inexhaustible source of energy, rallying availability and respect of the environment. The countries of North Africa are increasingly orienting their energy strategy towards renewable resources. The production of electricity from solar photovoltaic sources, widely available in most African countries, has many advantages and still presents some challenges to improve profitability. In the absence of state regulations, the business model is based on attractive selling prices comparing to the national operator. This pattern limits turnover and profitability. For a photovoltaic installation with a power of 10 Wp, the return on investment is over 9 years. The payback duration decreases to 5 years if the project receives a subsidy of 50% of the investment cost, the operational and maintenance costs being already low.

The governance of the Moroccan medium voltage electricity market requires financial assistance from the State. In the absence of proven profitability and despite a clear desire to develop photovoltaics, the acceleration of the transition still depends on subsidies and the legislative context. As the development of renewable energies is accelerated by the implementation of reforms and incentives; this is due to the abundance of fossil

resources in the face of the short-term economic non-profitability of the majority of investments in ecological energy. Professionals often find themselves facing a lack of government incentives and reform to make this transition.

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