Efficiency of Electricity Self-Production for Medium Voltage Subscribers in Tunisia

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Abstract

This paper discusses and studies the integration of photovoltaic plant connected to Medium Voltage (MV) network in the Tunisian energy mix and its competitiveness compared to other technologies, especially since the sale of MV electricity has grown to reach 34.17 % of all electricity sold by STEG (Société Tunisienne d'Electricité et de Gaz). It turned out to be a very competitive technology compared to mainly the centralized and decentralized photovoltaic plants with a Levelized Cost of Energy LCOE less than 0.160 TND/kWh.

Keywords: Tunisia Electricity Mix, Solar PV in medium voltage, OSeMOSYS.

1. Introduction

Energy transition in Tunisia is generally addressed as a technological and economic issue. Tunisian policy on energy is dominated by the national utility for electricity and gas named STEG. Since the independence, it has held a monopoly and enjoys forceful historical legitimacy for its achievements. Nevertheless, beginning the 2000s, national energy self-sufficiency was challenged (United Nations. 2017) so that the Tunisian government pushed for renewable energies. STEG was wary of these renewable technologies and has slowed its implementation. The Tunisian revolution has completely shaken the power's balance in the country, allowing for multi-level criticisms of STEG and for the making of new alliances for renewable energy projects. With the failed try of the Tunisian government to adapt regulatory and institutional frameworks to guarantee energy independence due to the continued uncertainty and oscillation of fossil fuels prices, the government was found under increasing pressure to create a long-term strategy towards energy self-sufficiency or in other words energy independence. Energy system models might be a tool for the decision makers in the country to draw an optimal long-term pathway for energy independence 5 (M. Howells et al. 2011), (OpenEnergy. July 2017), (OpenEnergy. October 2017) and (Energy Modelling. 2018). Which match the continuous increase in the demands, the availability of the Tunisian resources and the variability of prices.

In 2016, Tunisia adopted an energy strategy which aims to guarantee the security of supply of the country and ensure access to energy at an affordable price for the Tunisian economy. Tunisian energy policy aims to reduce primary energy consumption by 30% in 2030 (ANME. 2016) compared to the baseline scenario, while increasing the share of renewable energies in the Tunisian energy mix. So, in order not to miss the energy transition in Tunisia, we really have to think about some incentives that push MV subscribers to be self-producers, especially since the sale of MV electricity has grown to reach 6 956 GWh in 2019, which represents 34.17 % of all electricity sold by STEG as shown in figure 1.

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Fig. 1: Evolution of medium voltage electricity sales (STEG. 2015).

For the planning of national energy systems, different applications of energy systems modeling exist (Horizon. 2020). Decision makers are actually using some models to draw up long-term energy strategies like EnergyPLAN (D. Connolly et al. 2011), EU PRIMES (P. Capros *e*t al. 2016) and OSeMOSYS model. These applications share the characteristic of being bottom-up and optimization models. So that, they indicate the cost optimal pathways to decision makers to achieve given energy targets. Contrariwise, they differ by the type of modelling framework. While TIMES (R. Loulou. 2005) and PRIMES are partial equilibrium, MESSAGE (L. Schrattenholzer. 2016), and OSeMOSYS (Optimus community. 2017), (M. Welsch. 2015), (F. Gardumi. 2016) and (M. Welsch et al. 2012) are dynamic linear. And only OSeMOSYS is fully open source. The appropriate modelling framework is chosen based on the kind of insights the country model is intended to provide.

In order to help the decision makers with the elaboration of long-term strategies towards energy independence, we are going to study and discuss, in this paper, the integration of MV self-production in the Tunisian energy mix. So, we are going to identify whether this technology is a competitive one compared to mainly the centralized and decentralized photovoltaic installations or not.

2. Methodology

The modelling tool chosen for running this analysis is the Open-Source energy Modelling System – OSeMOSYS (M. Howells et al. 2011) and (F. Gardumi et al. 2021).

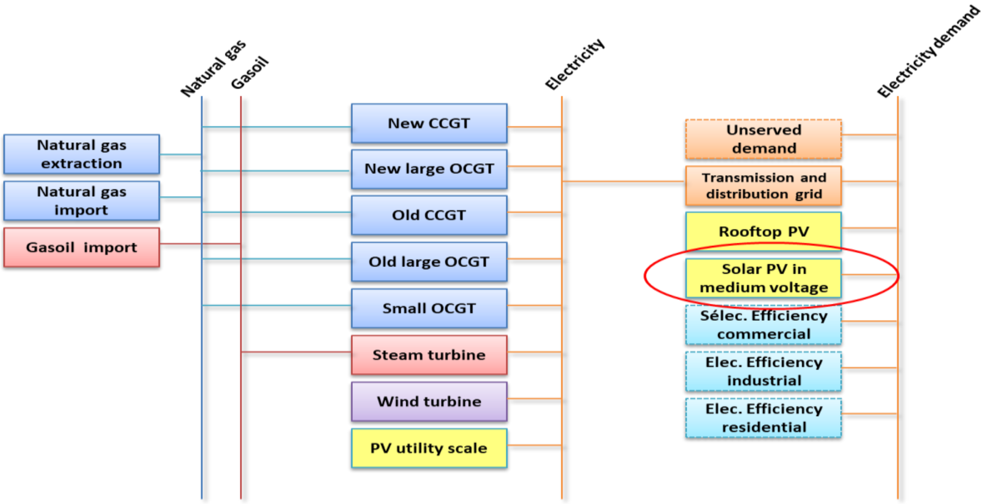

Fig. 2: Reference Energy System

The diagram represented in Figure 2 describes what in energy systems modelling is called a ‘Reference Energy System’ i.e. a simplified engineering scheme of the object of analysis. For the modelling, we started from a basic model called TENEM developed by the GIZ (The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH) and we added a new technology “Solar PV in medium voltage” to study its competitiveness compared to other technologies that generate electricity. The simulated model includes a number of supply chains connecting imported and domestic energy sources (both fossil and renewable) to the national electricity demand through aggregated conversion processes (e.g. extraction and import resources, conversion of primary sources to electricity, Transmission & Distribution network). As options for electricity supply from fossil fuels, all current gas power plants (open cycle gas turbines and both combined cycles) and the committed ones are represented separately. Energy efficiency options for the residential, commercial and industrial sectors are represented separately. They are considered as virtual technologies ‘absorbing’ part of the electricity demand. Each of the options is given specific user-defined techno-economic characteristics, used by the modelling tool to choose the future least-cost electricity supply mix. In this study we will focus on the efficiency of integrating the new technology “Solar PV in medium voltage” in the Tunisian energy mix.

3. Assumptions and Scenarios:

The sale of MV electricity is in the order of 6,956 GWh in 2019 (almost 25 PJ). To cover this demand, an installed capacity of 4.1 GWp is needed (given that each kWp produces 1700 kWh / year). Based on this data, we have identified 3 scenarios to consider:

- Scenario 1: slow progression in the power to be installed: that is to say, we will install each year a capacity equal to 0.041 GWp to achieve in 2045 a total capacity equal to 1.025 GWp allowing the satisfaction of 25% of electricity needs for MV subscribers in other words the satisfaction of 8.75% of electricity demand in Tunisia (since the MV electricity represents 35% of all electricity demand in Tunisia).
- Scenario 2: rapid increase in the capacity to be installed until reaching in 2045 the satisfaction of 50% of the electricity needs for MV subscribers. This represents 17.5% of electricity demand in Tunisia.
- Scenario 3: the max capacity investment parameter in OSeMOSYS software (expressed in GWp) is kept unlimited in order to see the economic efficiency of this new technology and its participation in the optimal energy mix in Tunisia.

For PV installations, we consider a new technology “Solar PV in medium voltage” which differs from the others by the cost of transport and the capital cost. In fact, for this technology we consider that the PV installations connected to the MV network are located near the consumption points so that the cost of transport is not considered like the case for the centralized installations. In addition, the capital cost considered is lower than the decentralized installations.

4. Results

It should be mentioned here that for all the scenarios, we kept the min capacity investment equal to zero. So, if the technology is not profitable and efficient, its participation in the Tunisian energy mix will be equal to zero.

Comparison of the first and second scenarios:

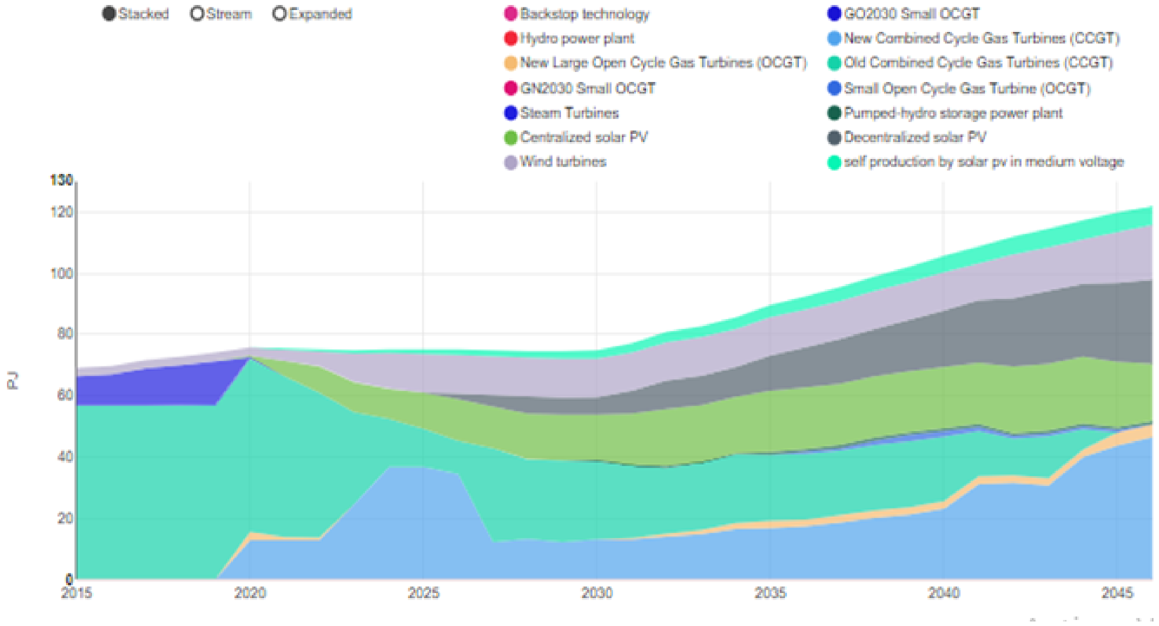

Fig. 3: Simulation of the first scenario of the Tunisian Electricity Mix (slow progression in the power to be installed)

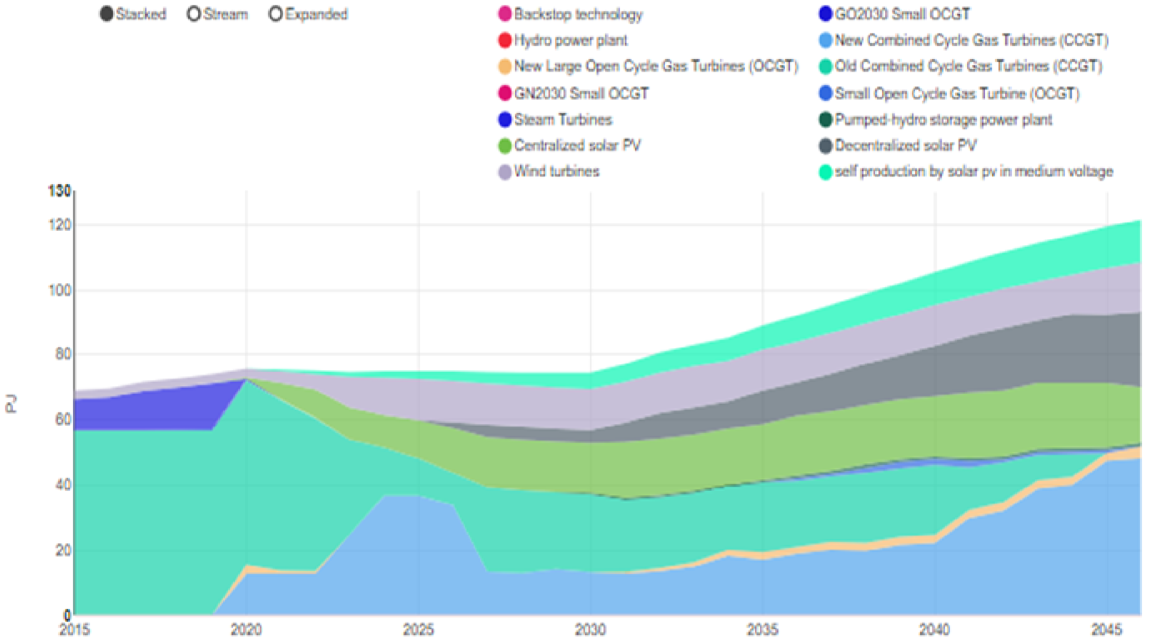

Fig. 4: Simulation of the second scenario of the Tunisian Electricity Mix (rapid increase in the capacity to be installed).

The simulation results show the significant participation of electricity produced from photovoltaic plants connected to the medium voltage grid in the totality of the final electricity produced despite the fact that the production of electricity from this technology has been limited for the first and second scenarios. In fact, for the first scenario, we fixed the max capacity investment for the new technology proposed so that we achieve, in 2045, 25% of the electricity demand for MV subscribers which is equivalent to 8.75% of the total final electricity demand. Likewise, for the second scenario, we acted on the max capacity investment to achieve 50% of MV electricity needs in 2045.

Comparison of the second and third scenarios :

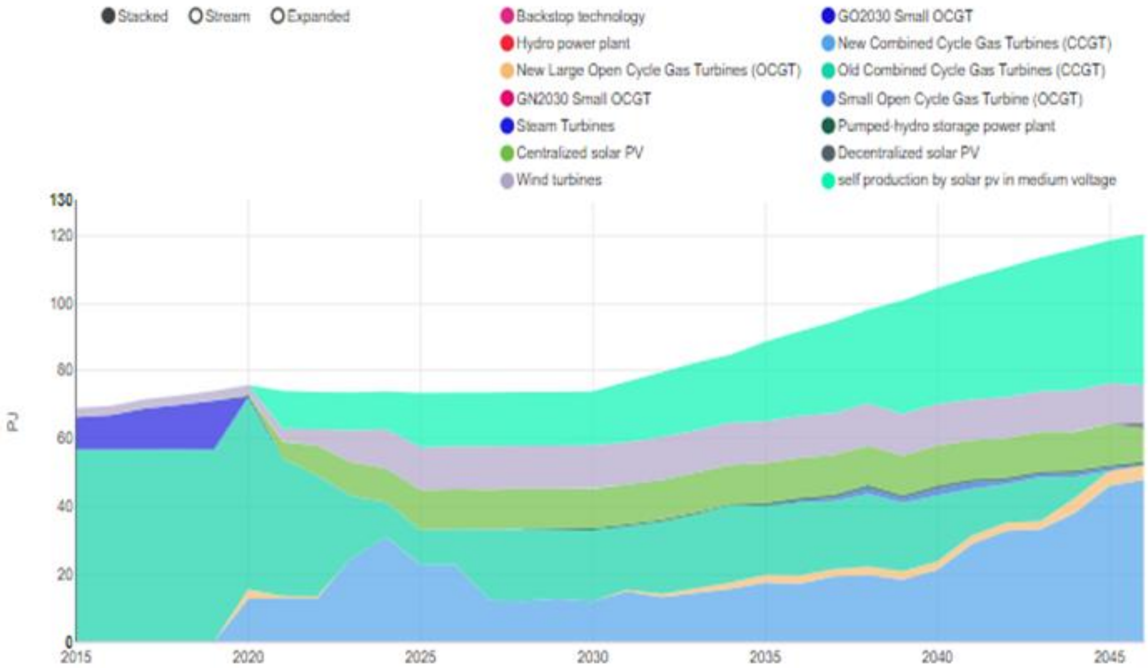

Fig. 5: Simulation of the third scenario of the Tunisian Electricity Mix (max capacity investment is kept illimited).

For the first and second scenarios, the max capacity investment was limited and in the simulation results we obtain every time the max of electricity production from the new proposed technology so we decided to maintain the max capacity investment for the third scenario unlimited to see what would be its participation in the Tunisian energy mix. The simulation results show that the new technology introduced is very competitive compared to other technologies especially compared to the decentralized solar PV technology which has practically disappeared and the centralized solar PV technology which has decreased in a very remarkable way. And this result is confirmed by the calculation of the LCOE. In fact, the LCOE for the first scenario is equal to 0.1618 TND/kWh versus 0.165 TND/ kWh for the basic scenario which did not include the new technology. The LCOE relative to the second scenario is equal to 0.1616 TND/kWh and the lowest value of LCOE is 0.1592 TND/kWh and it is relative to the third scenario.

Impact of the scenarios on LCOE:

In our study, the levelized cost of electricity and not energy was calculated by first taking the net present value of the total cost of the technologies. This number is then divided by the total electricity generation over its lifetime like it is shown in the equation.

$$\mathrm{LCOE} = \frac{\sum_t^n \left(\frac{operation\ cost}{(1+r)^t} + \frac{investment\ cost}{(1+r)^t}\right)}{\sum_t^n \frac{Production\ annual}{(1+r)^t}} \qquad (eq.\ 1)$$

Where n: number of years

t: counter

r: attenuation rate such as $r = \frac{i-\gamma}{1+\gamma}$=0.009

i: interest rate =6,25% .

γ: inflation rate =5.3% .

The calculation of the LCOEs of the different scenarios gave the following result:

Table 4: Impact of scenarios on LCOE

	Reference case: RES without the new technology	**Scenario 1:**	**Scenario 2:**	**Scenario 3 :**
LCOE (DT/kWh)	0,165	0,1618	0,1616	0,1592

Starting from the data obtained from the simulation results, LCOE was calculated for the reference case before adding the new technology and for each scenario after insertion the new technology. The results shown in Table 4 affirm that the more we invest in solar PV in medium voltage technology the more the cost of electricity decreases. This clearly shows the profitability of this technology.

Table 5: Gain in the subsidy on the cost of kWh

	Scenario 1:	**Scenario 2:**	**Scenario 3 :**
Gain of STEG in subsidy (in Million dinars)	173,9	347,8	1133,33

Assuming that the kWh is subsidized by 0.1 TND, we have therefore calculated the gain of STEG from this subsidy. And the result is shown in table 5.

For example, for the third scenario, we will have production by 2045 equal to 40.8 PJ = 11333.33 GWh. So, subsidy will be equal to 1133.33 million dinars in 2045.

Electricity consumption of MV subscribers represents 34% of total electricity. If they turn into self-producers 34% of the needs during peak hours will be met.

5. Conclusion

In this article, we studied the effect of the integration of photovoltaic systems connected to the medium voltage network in the Tunisian energy mix. It turned out to be a very competitive technology compared to other technologies especially since the lowest LCOE calculated is equal to 0.1592 TND/kWh and it is relative to the third scenario in which we did not limit the max capacity investment.So, in order not to miss the energy transition in Tunisia, we really have to think about some incentives that push MV subscribers to be self-producers.

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