GREEN ENERGY SEAPORT SUGGESTION FOR SUSTAINABLE DEVELOPMENT IN DAMIETTA PORT, EGYPT

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ABSTRACT

Having a sustainable, clean, efficient and economic environment is one of the main requirements of humanity. The seaport is such an environment, which needs care to be maintained as a sustainable green environment. This research provides a model for attaining a sustainable green port with the utilization of two mutual sequential renewable energies, which are Biomass and photovoltaic (PV) energy. This research plans to cover the whole electrical power generation of the seaport model after ten years using biomass and PV energy. Further, the research suggests the selling of extra electrical energy to the Egyptian Unified Electrical Power Network and the nearby loads. The project is held in two main stages. The first stage is the intermediate stage in which both green energy and the conventional electrical energy from the power grid will supply the port. In the second (final) stage, the green renewable energy will cover the consumption of the targeted seaport and sell the excess to the unified grid or the nearby costumers. The combination of biomass and PV electrical power generation can lead to an integrated efficient green energy port model. The research model will be applied to Damietta seaport, which is located 10 km to the west of the Nile River (Damietta Branch). It is assumed that by 2021 more than 50% of Damietta seaport electrical energy will be supplied by both biomass electrical generated energy and PV power generation. By 2026, green energy generation will have covered all the port requirements for electrical energy, and the extra power will have been diverted to the Egyptian unified electrical power network.

Keywords: sustainable development, green energy, clean-renewable energy, photovoltaic energy, biomass energy, seaport, Damietta seaport.

1 INTRODUCTION

Taking into consideration the expected shortage in the conventional electrical energy resources and the pollution increasing rate, environmentally friendly energy resources are considered to be the greatest targeted solution. This solution is preferred to be renewable. It is supported by the art of sustainable development. Biomass and photovoltaic (PV) energies are two examples of clean, renewable electrical-energy-generation resources [1]–[3].

Biomass energy is a remarkable renewable energy resource. It has been used since cave men discovered fire. Biomass did not received its name until the 1970s [4]. In the 1970s, scientists became interested in the possibility of replacing fossil fuels with biomasses. “Biomass” became the official name of the energy around 1975 [4]. Prior to the industrial revolution, biomass satisfied nearly all of man’s energy demands. Although presently the majority of humankind’s energy requirements are fulfilled by fossil fuel combustion, 14% of the world still utilize biomass. The thousands of tons of manure, mounds of agricultural waste and piles of sawdust can generate energy. Nowadays, the world population uses only about 7% of the annual production of biomass. Although biomass faces problems, with little investment in biomass research, which currently relegates biomass plants to small niche markets and individual’s efforts, new technologies are being developed and small-scale projects are becoming economically efficient and environmentally sustainable [5]–[7]. Recently, many researches in biomass energy discuss the thermal and/or the electrical returns of biogas. Such research mainly concentrates on the thermal energy

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section, even though the electrical power generation from biomass is a promising mission [8]–[10].

Lately, PV electrical power generation has been receiving considerable attention. It has some unique advantages over conventional power-generating systems. A PV system can be designed for a variety of applications and operational requirements. It can be used either as a stand-alone unit (distributed power generation) or connected to an electrical power grid. PV systems are static systems with sunlight fuel, which avoid noise and pollution. They are modular structures that are easily expandable and transportable in some cases. PV systems have two attractive features which are energy independence and environmental compatibility. In general, well designed and properly installed PV systems require minimal maintenance and have long-service lifetimes [1]–[3], [6], [7]. The first conventional PV cells were produced in the late 1950s [11]. In the 1970s, improvements in manufacturing, performance and quality of PV modules helped to reduce costs. PV systems opened up a number of opportunities for powering remote terrestrial applications, including battery charging for navigational aids, signals, telecommunications equipment and other critical, low-power needs. Following the energy crises of the 1970s, significant efforts also began to develop PV power systems for residential and commercial uses, both for stand-alone, remote power and utility-connected applications. Today, the industry's production of PV modules is growing significantly. The major programs in US, Japan and Europe are rapidly accelerating the implementation of PV systems on buildings and interconnection to utility networks [11]–[13].

Seaports are one of the vital environmental societies which emit different types of contaminants that affect the overall percentage of the atmospheric pollution. The sustainable green seaport technologies are supported by many researches and projects [14]–[16]. A green port – also known as an ecological port – is a sustainable development port that does not only meet the environmental requirements, but also raises their economic interests. The main objective of the ecological port is to create a good ecological environment and high economic efficiency in the port, and to ensure the overall harmonious and sustainable construction of the community's economic, environmental complex ecosystem in the port. In addition, it aims to establish the leading position of ports in modern transportation, logistics, port services, and integrated industrial systems [17]. Egypt coasts contain 15 commercial and 44 specialized ports [18]. In this paper, a model of a green energy seaport, which is supplied by clean renewable electrical energy, is discussed and applied to one of the Egyptian seaports.

2 BIOMASS AND PHOTOVOLTAICS

2.1 Biomass

Biomass is a carbon-based material that is composed of a mixture of organic molecules, containing hydrogen, which usually includes atoms of oxygen, often nitrogen and also small quantities of other atoms, such as alkali, alkaline earth and heavy metals [19]. Biogas is a form of energy produced when organic materials from biomass are bio-chemically broken down under anaerobic conditions [20]. Biogas is a combustible gas, which has an average calorific value of ca. 6 kWh/m^3. The amount of biogas produced depends on the different parameters of the processed chemical reaction. The type of the bio-waste and its Total Solids Percentage (TS%) are taken into consideration with reference to the affective parameters. There are many techniques for utilizing biomass, such as alcohol fermentation, landfill gas, and gasification. The newest method for electricity generation is known as gasification. This method captures 65–70% of the energy present in solid fuels by first converting it to combustible gases. These gases are then burned, like natural gas, and create energy. The technologies for this synthetic fuel (synfuel) are still new [5]–[9]. The working principle and integration in a biomass plant are presented in Fig. 1 [21], [22].

2.2 Photovoltaic

Photovoltaic is the electrical energy which can by generated from the solar energy. Its generation rate varies due to many different factors, such as the cell material, solar irradiance, incident angle, surrounded temperature, etc. The average photovoltaic power generation in Egypt is around 6 Kwh/m^2 per day. The distribution of the solar energy intensity (in kWh/m^2/day) over Egypt is shown in Fig. 2 [23], [24].

The output generated electrical energy (in kWh) from the photovoltaic unit can be calculated using eqn (1). Eqn (2) is used to convert the electrical energy (in kWh) into its equivalent power (in kW).

$$E = A \times r \times H \times PR, \tag{1}$$

$$P = E / t, \tag{2}$$

where,

E = Energy (in kWh).
A = Total solar panel area (in m^2).
r = Solar panel yield or efficiency (%).
H = Annual average solar radiation on tilted panels (shadings not included).
PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75).
P = Power (in kW).
t = Consumption time (in hours).

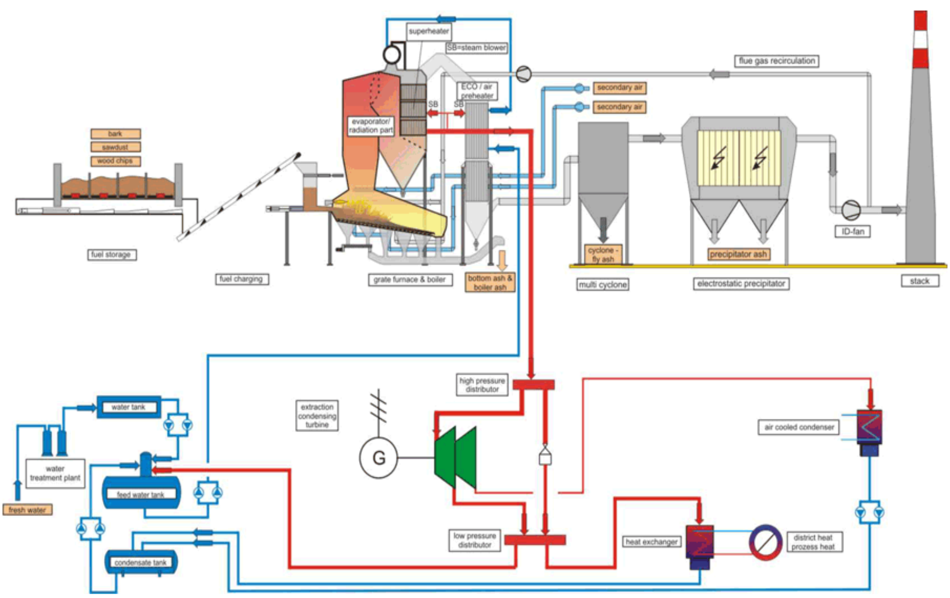

Figure 1: Working principle and integration in a biomass plant [21], [22].

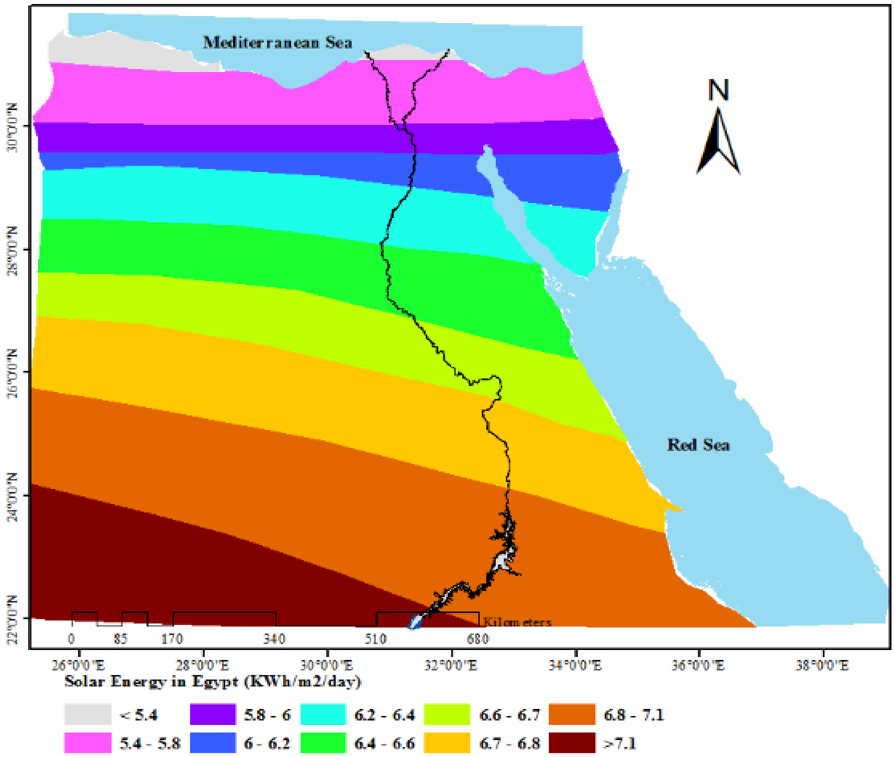

Figure 2: Solar energy intensity in Egypt [23], [24].

3 DAMIETTA PORT

The Port of Damietta is an ancient city that lies on the east bank of the Damietta branch of the Nile River in Egypt. The Port of Damietta is about 40 nautical miles (56 kilometers or 35 miles) northwest of Port Said and about 112 nautical miles (184 kilometers or 114 miles) east-northeast of the Port of Alexandria. When the Mahmudiyyah Canal was built in 1819, much of the Port of Damietta's trade was diverted to Alexandria. Almost 77,000 people live in the city, as well as in the Port of Damietta [25].

The Port of Damietta is the capital of the Damietta Governorate of Egypt, reported to be the wealthiest governorate in the country. Nowadays, the channel has been dredged and port facilities upgraded so that the Port of Damietta is able relieve maritime congestion in Alexandria. Major industries in the Port of Damietta include the manufacture of clothing and furniture, leather working, fishing, and flour milling.

Today, a canal connects the Port of Damietta to the Nile, making it an important maritime center where containers make up much of the cargo volume. The Port of Damietta now contains a liquefied natural gas plant, and a methanol plant producing 1.3 million tons per year that reaches the global methanol market. The Port of Damietta is also a busy fishing port.

The port of Damietta is about 8.5 km to the west of the Damietta branch of the River Nile. It is on the Mediterranean Sea to the west of Ras El Bar. Damietta Port is 70 km to the west of Port-Said and 200 km from Alexandria port. The total port area is about 11.8 mm^2, Water area is 3.9 mm^2, which will increase to 4.5 mm^2, and land area is about 7.9 mm^2, which will increase to 8.6 mm^2. The ratio of water area to total port area is around 1:3 [26]–[28]. The port description can be summarized as follows:

a. Entrance Channel: the channel is 11.3 km long and 300 m wide. This gradually decreases until it reaches 250 m at breakwater and 15 m depth. The channel is surrounded by 18 buoys which are lit at night, odd numbers on the right and even numbers on the left. There is an external waiting area.
b. Breakwater: the West breakwater is 1640 m long (140 m in land and 1500 m in the sea). The East breakwater is 738 m long (200 m in land and 538 m in the sea). The breakwaters are protected from the external side by the industrial acrid bocks. They are topped by a cement layer.
c. Barge Canal: this consists of two ports; one is 1350 m that links the barges basin to the sea and the other is 3750 m that links the basin to the Nile branch. The area of the barge basin is 250 × 250 m^2. It is equipped with a berth of 250 m long where the water depth is 5 m. The diameter of the rotation basin is 500 m and its depth is 14.5 m in front of the container terminal and 12 m in front of the general cargo quay.
d. Port dimensions: an imaginary line links the two ends of the external East and West breakwaters.

Two maps for illustrating Damietta Port's location in Egypt are presented in Fig. 3. Fig. 3(a) shows a general view of Damietta's location in Egypt [27], while Fig. 3(b) represents a zoom-in view [29]. The Damietta seaport plan is illustrated in Fig. 4 [30].

The ship traffic at Damietta Port during the 3rd quarter of 2016 (July–September) is illustrated in Table 1 [26].

(a) (b)

Figure 3: Damietta port's location in Egypt. (a) General view of Damietta's location in Egypt [27]; (b) Close-up view of Damietta Port [29].

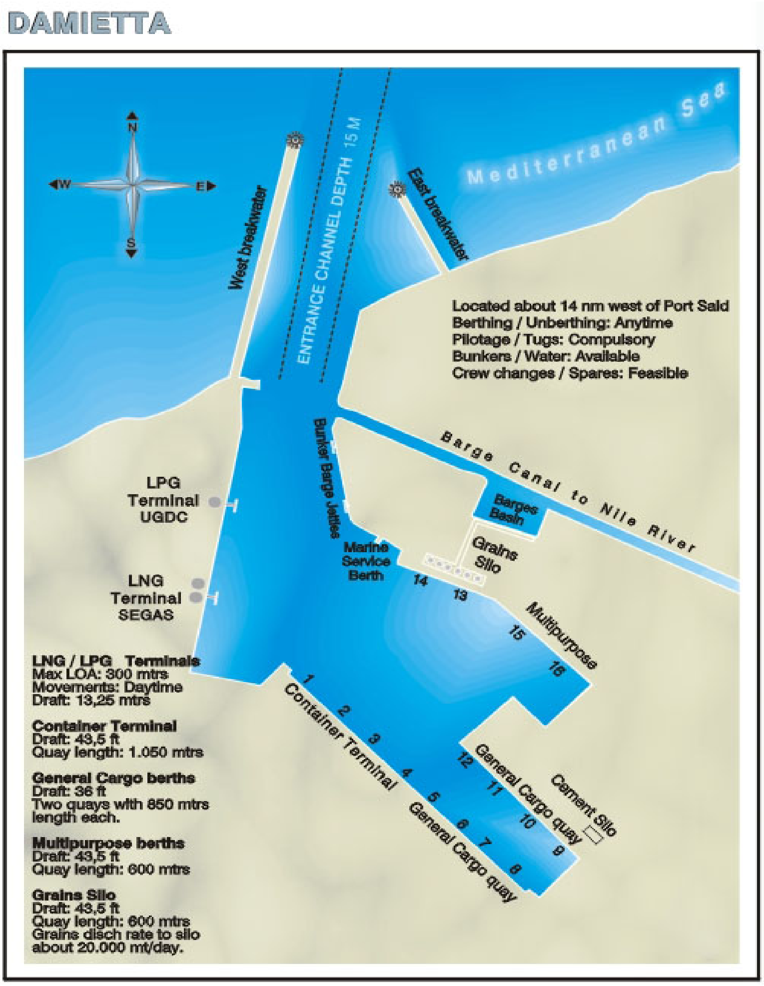

Figure 4: Damietta Port plan [30].

Table 1: Ship traffic at Damietta Port during 2016 (July–August–September) [26].

Index	Container	General cargo	Dry bulk	Liquid bulk	Special	Total
3rd quarter of 2016	276	129	159	19	16	599

4 DAMIETTA PORT PROPOSED PROJECT

The suggested developed project is aimed to design, simulate, implement and follow-up a green energy seaport model, which is supplied by environmentally friendly electrical energy. The developed model suggests a gradual replacement of the fossil fuel electrical power utility by clean renewable electrical power resources. Photovoltaics and biomass are the main two proposed electrical energy resources.

Two evaluated stages will progress to reach the targeted complete substitution of conventional electrical power. Starting from the current situation, at which all of the port's electrical consumption is covered by fossil fuel electrical power, the project will pass through an intermediate evaluated stage to reach the productive final stage. During the intermediate stage, an integration between the electrical power utility and the port's green generated power takes place to cover the overall port consumption from electrical energy. The sustainable green electrical power will provide the port with its total electrical power requirements during the productive final stage. In addition, extra generated electrical power can be sold to the power utility network and neighboring consumers. Fig. 5 illustrates the different stages of electrical energy generation in the implemented project.

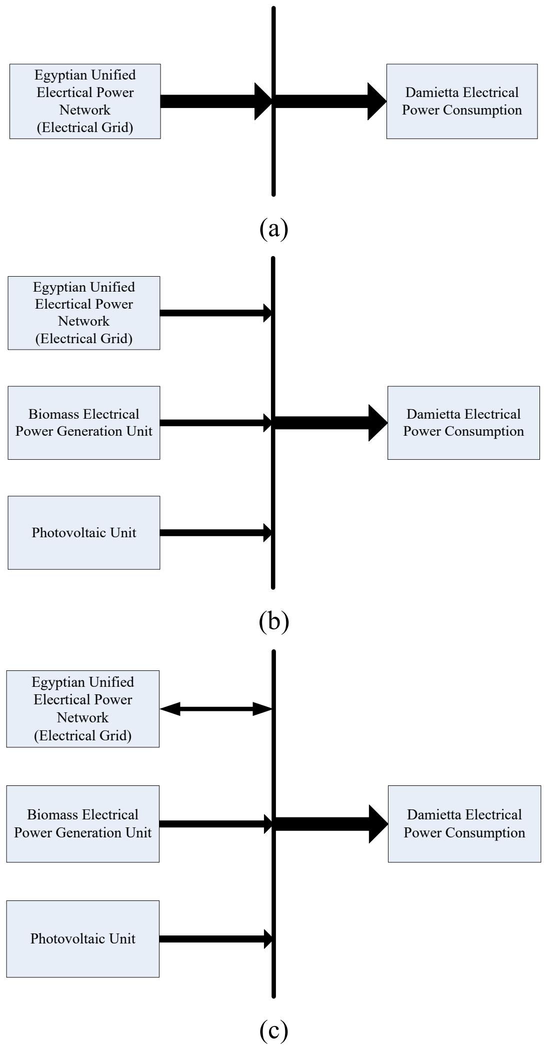

Figure 5: Different stages of electrical energy generation in the implemented project. (a) Current situation; (b) Intermediate evaluated situation; (c) Final (productive) situation.

The suggested project will be applied to Damietta seaport as a studied model. Referring to the collected data from the Damietta Port Authority in November 2016, the port's average electrical power consumption is 8 MW/day. The total port area is about 9297 km^2 (9297 × 106 m^2), including 3933 km^2 (3933 × 106 m^2) water area. The average human capacity is around 40,000 persons. The port's daily average capacity of organic waste is 15 tons/day. Table 2 summarizes the aforementioned information about Damietta Port.

The average daily solar energy in Damietta is approximately 4 kWh/m^2 [23], [24]. The variation of the average daily Damietta global solar radiation through the different months of the year is presented in Fig. 6 [31].

It is assumed that PV panels will be implemented in 1/5 of the port land area ($A \approx 1.1$ km^2) before 2026. By substituting in eqn (1), the supposed PV generated energy per day will be 430 MWh. It can produce 17.9 MW daily. The storage techniques of the excess generated power would, however, present a problem.

It is suggested that all the organic waste capacity will be processed through biomass reactors to be converted into biogas. The biogas will be utilized in generating electrical power. According to practical experience in biomass energy generation, each ton of organic waste can produce from 2 to 15 (2–15 m^3/day) of biogas depending on the Total Solids percentage (TS%). Every cubic meter of biogas can generate from 1.7 to 2 kW electrical power. In Damietta Port, the equivalent value of the daily organic waste (15 tons) can be converted from 51 kW to 450 kW. Therefore, the average electrical generated power from biomass will be about 0.25 MW/day.

Table 2: Some information about Damietta Port.

Total port area	92,96,911.45 m^2
Water area	39,33,123.16 m^2
Land area	53,63,788.29 m^2
Port's average electrical power consumption per day	8 MW/day
Port's human capacity (manpower)	40,000 persons
Port's average capacity of organic wastes per day	15 tons/day

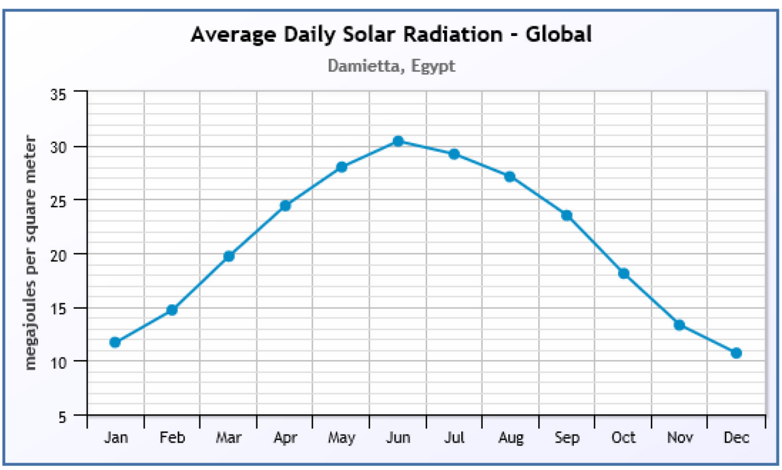

Figure 6: Average daily Damietta global solar radiation (in Mj/m^2) per month [31].

The share of the electric power utility (the Egyptian Unified Electrical Power Network (EUEPN)) and each green electrical power source in covering the port consumption is illustrated in Table 3 and Fig. 7. Both Table 3 and Fig. 7 clarify the variation of the amounts of the combined energy starting from 2017 to 2026. By 2026, the Damietta Port generation unit will be ready to sell as power to the EUEPN and nearby consumers.

5 CONCLUSION

Presenting a green energy seaport as a model for an environmentally friendly electrical energy generation unit is the main objective of this research. It is suggested to be one of the sustainable fields of development in Egyptian seaports. The suggested model is based upon the gradual replacement of conventional electrical power sources in seaports by renewable sustainable ones. In this project, biomass and photovoltaics are employed for electrical power generation in the developed model. The electrical power consumption of the seaport

Table 3: The share of EUEPN, biomass and PV electrical power in covering Damietta Port's electrical consumption.

Year	EUEPN power (in MW/day)	Biomass power (in MW/day)	PV power (in MW/day)	Total delivered power (in MW/day)	Total electrical consumption (in MW/day)
2017	8	0	0	8	8
2018	6.75	0.25	1	8	8
2019	5.25	0.25	3	8.5	8.5
2020	3.25	0.25	5	8.5	8.5
2021	2.25	0.25	6.5	9	9
2022	0.5	0.5	8	9	9
2023	scheduled according requirements	0.5	10	10.5	9.5
2024		0.5	12	12.5	9.5
2025		0.5	13	13.5	10
2026		0.5	13	13.5	10

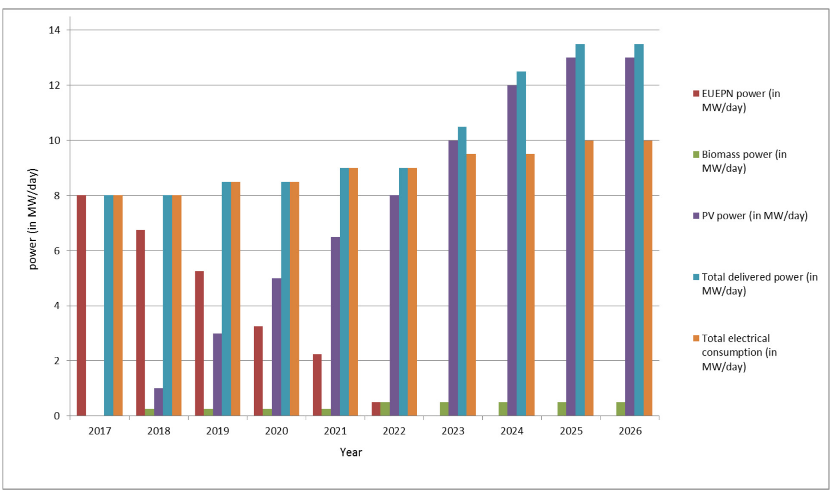

Figure 7: The supplied and consumed electrical power within the duration of the project.

model will be completely covered after ten years by both biomass and photovoltaics. It is also proposed that the extra electrical energy be sold to the Egyptian Unified Electrical Power Network and the neighboring loads. Damietta Port will be the structure under study for the suggested project. The project starts from the port's current situation, passing through two main stages – the intermediate stage and the final (productive) stage. In the intermediate stage, the port's electrical consumption will be supplied mutually by the generated green energy and the conventional electrical energy from the power grid. In the productive final stage, the green sustainable energy will cover the electrical demands of the targeted seaport and the excess power will be marketed. The combination of biomass and photovoltaic electrical power generation can lead to an integrated efficient green energy port model. By 2021, the combination of biomass and photovoltaic electrical power generation is assumed to generate around 6.75 MW/day which is 75% of the electrical energy of Damietta seaport. The green energy generation should reach 13.5 MW/day by 2026. It is assumed to cover all the port requirements from electrical energy (10 MW/day). The extra generated renewable power will be sold.

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