Research Article

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A case study on the environmental and economic impact of photovoltaic systems in wastewater treatment plants

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Abstract: Ibn Tofail University of Kenitra, Morocco, is committed to a national policy of control and mobilization of water resources and the adoption of a planning approach and integrated water management. Within this framework, the university, which contains 40,000 students, produces a quantity of wastewater of 200 m^3 per day. After treatment, the water is used for watering the university's green space. The treatment process chosen is a membrane bioreactor (MBR), which is considered to be energy intensive. Therefore, the production of energy for the station will be made by renewable energy wind and photovoltaic (PV). The dimensioning of the MBR was made by a research department, which estimated that the energy necessary for the station is 1061.76 kW h/day. The aim of this work is to dimension and optimize the platform for the production of energy, using the Matlab program for the wind turbine and the PVsyst program for PV. The results of coupling our plant with an on-grid PV system and wind turbine show that it was able to reach an electrical coverage of about 72% of the wastewater treatment (WWT) plant's energy needs. Thus, an estimated reduction of electricity of 0.53 euro on each m^3 of water produced by the WWT plant and thus 106.76 euro on the 200 m^3 produced daily by the station.

Keywords: membrane bioreactor, wastewater treatment, renewable energy, photovoltaic, wind turbine

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1 Introduction

Ibn Tofail University of Kenitra, Morocco, is among the universities that give importance to clean energy and wastewater treatment (WWT). Within the framework of environmental preservation, it is strongly involved in environmental issues and participates actively in the realization of sustainable green projects, which has given it the identity of a "green and open university." Ibn Tofail University is ranked among the best universities in the field of clean energy and water treatment in the world [1]. Due to the high consumption of energy and the multiple uses of water, the university decided to take the initiative to exploit scientific research in the development of natural resources. Creating a set of projects benefits the university and stimulates constructive scientific research aimed at making Ibn Tofaïl University a "SMART University." Indeed, the university had already carried out a project of solar energy production in order to reduce the operating bill and a project of the construction of a WWT plant, which is underway in order to reuse the treated water in the watering of any green space of the university. Global sustainable development is based on the link between energy and water as essential resources and, indeed, has been the subject of several recent research [2,3]. In addition to examining the average energy usage for each cubic meter of treated water. Therefore, the optimization of energy in WWT plants is an option for reducing electricity costs and energy savings [4,5]. The sludge produced can be used as an energy source, which could contribute to waste management and environmental sustainability [6].

The problem of concerns about global climate change and rising energy prices requires the use of alternative energy sources to ensure the energy independence of the station. It can be solved through saving energy by improving the efficiency of unit processes and obtaining energy from renewable energy sources, solar energy, wind energy [7] or a grid-connected solar-wind hybrid system and therefore human development [8]. The use of clean energy, solar energy, wind energy, and biodiesel [9] has grown rapidly lately, and the associated costs are decreasing. These are naturally replenishing energy sources. is an alternative to current and future scenarios, For energy production and reducing carbon emissions and environmental pollution [10,11]. This transition to renewable energy – wind, solar, and solar–wind hybrid systems – has become an essential option for powering membrane desalination processes [12], and WWT plants. Huang *et al.* [13,14] and Li *et al.* [15] examined wind turbine significance with the help of a simple numerical technique in the presence of monopile foundation and noise labels and wind power forecast *via* a modified hidden Markov model, respectively. Yan and Wen [16], Song *et al.* [17], and Zhang *et al.* [18] recently considered electricity theft detection based on extreme gradient boosting, fast iterative-interpolated DFT phasor estimator, and time windows in a time-dependent traffic environment, respectively.

In Morocco, the activated sludge treatment process is used to treat urban wastewater and eliminate heavy metals present in domestic and industrial wastewater [19]. It is the result of the coupling of a biological treatment process with membrane separation. There are several WWT plants in Morocco using the membrane bioreactor (MBR) process, the largest of which is the Marrakech city plant, which is powered by a 300 kW solar photovoltaic (PV) plant and is capable of treating up to 60,000 m^3 of wastewater per day, and provides about 20% of the electricity needed to operate the plant. In addition to establishing other stations, such as the Casablanca station which uses the BRM process and which has the capacity to treat up to 200,000 m^3 of wastewater per day. The University IBN TOFAIL has also chosen the biological process to treat its wastewater because it is effective and meets the standards required by the ITU. WWT plants, in general, are supplied with electrical energy from the public grid. Scientific research has proposed the use of renewable energy as a source of energy for powering sewage treatment plants [20], which need a lot of electricity. Due to the sludge treatment process and the electrical load remaining stable does not change because it operates continuously [21]. The most common renewable energy source of power generation for WWT plant is solar PV and wind [22], because the sun and wind are inexhaustible sources. Tian *et al.* [23], Su *et al.* [24], and Xiao *et al.* [25] investigated environmental assessment of SOFC-based cogeneration system, high-efficient and salt-rejecting 2D film for photothermal evaporation and energy conversion in a thermo-osmotic system using low-grade heat. Liu *et al.* [26], Chen *et al.* [27], and Zhu *et al.* [28] scrutinized the alleviation of regional integrated energy framework in the presence of cross-system failures, low-carbon economic dispatch of integrated energy system and DFIG-based wind turbines, respectively.

Power generation from solar energy is a less expensive option; in fact, WWTP-PV projects can adopt the self-consumption mode of energy and increase their economic performance [29,30]. The grid-connected PV system can cover 53% of the treatment plant's electrical load and inject 510 MW h/year into the grid, which is 65% of the load [5,31]. A study has also been analyzed combining a PV system with wind turbines, in which case an energy efficiency of 90% [32], and another study was conducted whose purpose of a sewage treatment plant, 100% renewable by combining a PV system with a wind turbine system to absorb excess electricity production [22,33]. Long-term optimization strategies that take into account the technological limitations of a system and the possibility of using grid-connected PV energy are suggested. This is accomplished by using an alternative energy source to offset a specific percentage of the plant's overall annual energy consumption [5]. Wind technologies can be operated with average annual wind speeds of 5.6 m/s or higher is suitable for wind power installations [34]. Integrating renewable, solar, and wind energy in the water sector leads to energy independence and improved community and environmental health. Previous studies [35–37] highlighted the significance of the energy optimal schedule method for distribution networks with generation and energy storage, virtual synchronous generators based on energy reshaping, and temperature monitoring method for IGBT modules *via* CNN technique. Liao *et al.* [38] and Jiang *et al.* [39], respectively, depicted the physical importance of power smoothing of the wind energy systems and the performance of power to gas storage technology integrated with energy hub system.

The objective of this study is to power the WWT plant using renewable energy. It is PV or wind energy or a combination of both connected to the electrical distribution network. The Ibn Tofail University WWT plant is of an average size equivalent to 40,000 population equivalents (PEs), located in the city of Kenitra, in the North-East of Morocco. The PV and wind power system was dimensioned using PVsyst and Matlab Simulink software. A survey of the power requirements of the treatment plant and measurement of the electrical power demand per wet day and dry day was carried out. A proposal for a combined wind and

PV system was also sized. The actual prices of the components available on the local market were used to evaluate the total cost of electricity production and m^3 of treated wastewater.

2 Technical-economic study of the installation of self-consumption of electricity PV/wind turbine

2.1 Geographical conditions of Kenitra

Country: Morocco, Latitude: 34.30 North, Longitude: −6.60 West and Altitude: 14.

Secondary data related to the energy part of the WWT systems of the Ibn Tofail plant are collected, analyzed, and applied to a case study (Figure 1). The WWT plant, located in the city of Kenitra in the North-East of Morocco, was selected because of its available data. Meteonorm is the source of all the data we used in this study, as it is software that provides access to many meteorological data (irradiation, temperature, wind speed, *etc.*) necessary for the design and development of applications and systems using solar and wind energy [40].

2.2 WWT plant of Ibn Tofail University

The treatment plant of the university Ibn Tofail is a representative treatment plant that extends over an area of about 1,000 m^2 with a nominal capacity of 200 m^3/day with an energy consumption of 1061.76 kW h/day (Table 1), which was chosen as a test site for this study (Figure 2, red color). The treatment plant considered is equipped with mechanical and biological treatment stages of aerobic type, coupled

Figure 1: WWT plant of Ibn Tofail University.

Table 1: Consumption balance of the WWTP

				Voltage	400 (V)	Frequency		50 (Hz)					
Consumer data			**Power required**			**Power installed**		**Motor data**				**Miscellaneous**	
Consumer	**Total number**	**Number of function**	**Total simultaneous apparent power (kAV)**	**Active power (kW)**	**Simultaneity factor**	**Puissance apparent (kWV)**	**Active power (kW)**	**Power (Kw)**	**Number of Poles**	**Power factor**	**Yield (%)**	**Stand By**	**Start type**
Lift pump	2	1	5.8	4.7	1.00	5.8	4.7	4.2		0.8	90.0		Direct
Pretreatment	1	1	2.9	2.3	1.00	2.9	2.3	2.2		0.8	90.0		Direct
BT pump	2	1	1.8	1.4	1.00	1.8	1.4	1.3		0.8	90.0		Direct
BT stirrer	1	1	2.6	2.1	1.00	2.6	2.1	1.9		0.8	90.0		Direct
Bwer aeration	3	2	15.3	12.2	1.00	15.3	12.2	5.5		0.8	90.0		Direct
Alm MBR pump	2	1	1.7	1.3	1.00	1.7	1.3	1.2		0.8	90.0		Direct
Recir sludge pump	2	1	1.9	1.6	1.00	1.9	1.6	1.4		0.8	90.0		Direct
Permeate pump	2	1	2.1	1.7	1.00	2.1	1.7	1.5		0.8	90.0		Direct
MBR blower	1	1	7.6	6.1	1.00	7.6	6.1	5.5		0.8	90.0		Direct
C.I.P pump	1	1	0.0	0.0	1.00	1.5	1.2	1.1		0.8	90.0		Direct
CIP stirrer	1	1	0.0	0.0	1.00	0.5	0.4	0.4		0.8	90.0		Direct
Sludge trai pump	1	1	0.8	0.6	1.00	0.8	0.6	0.6		0.8	90.0		Direct
Sludge treatment	1	1	2.8	2.2	1.00	2.8	2.2	2.0		0.8	90.0		Direct
Coal tower	2	2	3.1	2.4	1.00	3.1	2.4	1.1		0.8	90.0		Direct
Handling	1	1	0.4	0.4	1.00	0.4	0.4	0.3		0.8	90.0		Direct
Instrumentation	1	1	2.2	2.0	1.00	2.2	2.0	—	—	0.9			
Inside lighting	1	1	1.1	1.0	1.00	1.1	1.0	—	—	0.9			
Exterior lighting	1	1	1.1	1.0	1.00	1.1	1.0	—	—	0.9			
Plug	1	1	2.0	2.0	1.00	2.0	—	—	—	—			
				The total apparent power	55.3 kVA								

Figure 2: Satellite view of the WWTP (exploitable part for the renewable energy installation in red).

with a membrane process of ultrafiltration type, immersed in the membrane tank, and has a built capacity of 40,000 PE. The WWTP employs an activated sludge process, and our site evaluation suggested that energy production from solar PV and wind power is due to favorable conditions. The Ibn Tofail WWT plant was selected because of its available data. Regarding the station's energy requirements, we decided to employ renewable energy sources. Given the city of Kenitra's reliable power grid, utilizing batteries would not be cost-effective. Instead, we chose to combine wind and PV systems to enhance energy coverage throughout the day and achieve a satisfactory percentage of coverage throughout the year. The operation of the WWTP is 24 h/24 and 7 days/7 in order to treat the wastewater volumes.

2.3 PV system specifications

Depending on the season, the angle of the sunlight varies [41]. Keep solar irradiation as well as the tilt angle of the PV panels equal to the latitude of the corresponding location to have maximum energy and solar radiation [42]. For the site, Ibn Tofail, the optimal tilt angle of the PV array was estimated to be 35°, which is within the range of latitude in the simulated area and an azimuth angle of 0°. This PV field will be south-facing, and the modules used will be monocrystalline. In our study, the simulations were carried out with the program PVsyst, which is characterized by a simple procedure and the ability to import meteorological data. Also, it contains a large database of models of PV panels and inverters, and it offers the possibility of setting the required power and the characteristics of the area of interest. PVsyst provides detailed technical analysis in several applications such as pumped solar, grid-connected PV, and even stand-alone systems; the energy results of PVsyst software are close to the actual measured data with a small difference [43]. The power of our PV system has been estimated to be 36 kWp to guarantee maximum production while avoiding excess energy loss.

Here, 10 parallel strings of 12 PV modules in series, model 72M-300. PV monocrystalline with an inverter model HPC-030HT was proposed for our simulation. Thus, we had an expected production of 48.35 MW h/year and consequently a deliverability of 1,343 kW h/kWp/year.

Figure 3 shows the daily energy consumption for the four seasons. According to the figure, summer is the period of the highest energy consumption. There is a slight decrease in autumn, but the energy consumption is divided by two in spring and winter. In the first step of the PVsyst procedure, we select the geographical area of interest. The weather data are automatically imported into the software. The geographical orientation of the WWTP location, the angle of inclination of the ground where they are installed, the type of PV panels, and the number of inverters and modules were chosen.

Our research is entirely based on the PVsyst software. The software is used for modeling purposes. The graphs and tables presented here in the documentation were generated only during simulations at the Ibn Tofail site. Since this article represents computer modeling, we only provide simulation results that we have obtained.

The consumption of the Ibn Tofail site. This represents the average of the monthly energy injected into the network in MW h. The maximum energy injected into the network in December was 5.050 MW h (Table 2). The smallest amount of energy pumped into the network in June

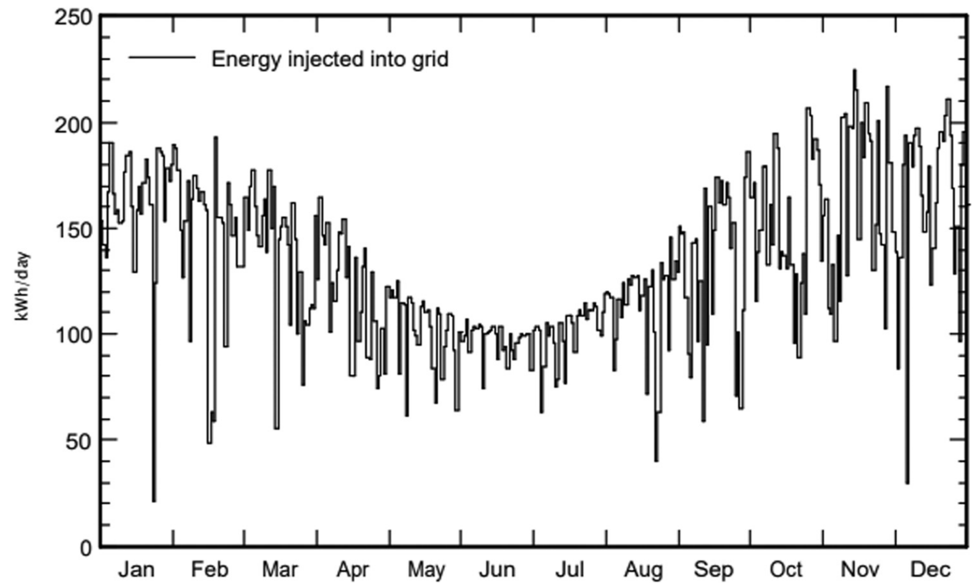

Figure 3: Daily energy at the field exit.

Table 2: Energy injected into the grid

Month	E_Grid (MW h)
January	4.973
February	4.094
March	4.281
April	3.571
May	3.155
June	2.911
July	3.140
August	3.528
September	3.988
October	4.711
November	4.944
December	5.050
Year	48.346

was 2.911 MW h. 48.346 MW h/year of energy has been added to the network overall.

The performance ratio (PR) is the ratio of the final PV system yield (Y_f) and the reference yield (Y_r) [10]

$$PR = \frac{Y_f}{Y_r}. \quad (1)$$

The PR of the network-connected system for the Ibn Tofail site is described in Table 3. The PR is 0.775 on an annualized basis.

The meteorological and incident energy of the PV system is shown in Table 4. The global horizontal irradiation (GlobHor) is 1,988 kW h/m^2/year. The horizontal diffuse irradiation (DiffHor) is 979.55 kW h/m^2. The collecting plane has a total incident energy of 1733.7 kW h/m^2.

Table 3: Normalized performance coefficients – PVsyst simulation

Month	Yr (kW h/m^2 day)	Lc	Ya (kW h/kWp/day)	Ls	Yf (kW h/kWp/day)	Lcr	Lsr	PR
January	5.82	1.127	4.69	0.232	4.46	0.194	0.040	0.766
February	5.26	0.993	4.27	0.210	4.06	0.189	0.040	0.771
March	4.96	0.922	4.04	0.205	3.84	0.186	0.041	0.773
April	4.28	0.775	3.50	0.197	3.31	0.181	0.046	0.773
May	3.65	0.949	3.00	0.177	2.83	0.178	0.048	0.774
June	3.46	0.597	2.87	0.172	2.70	0.172	0.050	0.778
July	3.59	0.603	2.98	0.170	2.81	0.168	0.047	0.785
August	4.01	0.665	3.35	0.184	3.16	0.166	0.046	0.788
September	4.72	0.826	3.90	0.203	3.69	0.175	0.043	0.782
October	5.43	0.993	4.44	0.218	4.22	0.183	0.040	0.777
November	5.92	0.113	4.81	0.232	4.58	0.188	0.039	0.773
December	5.92	0.152	4.77	0.241	4.52	0.195	0.041	0.765
Year	4.75	0.867	3.88	0.203	3.68	0.183	0.043	0.775

Table 4: Meteo and incident energy – PVsyst simulation

Month	GlobHor (kW h/m^2)	DiffHor (kW h/m^2)	T_Amb (°C)	Windvel (m/s)	GlobInc (kW h/m^2)	DifSInc (kW h/m^2)	Alb_Inc (kW h/m^2)
January	167.9	88.63	27.63	2.4	180.3	90.28	3.036
February	148.6	85.18	27.97	2.6	147.4	82.04	2.686
March	170.8	92.72	28.17	2.6	153.8	84.39	3.089
April	163.7	77.95	27.43	2.6	128.3	66.20	2.954
May	163.4	80.45	27.40	3.0	113.2	64.50	2.940
June	162.6	73.18	25.58	3.5	103.9	56.68	2.928
July	169.2	73.43	24.93	3.6	111.2	57.74	3.044
August	167.3	82.78	25.33	3.7	124.3	68.35	3.954
September	167.2	75.96	25.76	3.7	141.7	67.42	3.015
October	174.6	85.71	26.50	3.2	168.4	81.48	3.023
November	167.0	81.36	26.33	2.8	177.7	81.87	3.019
December	165.6	82.20	27.20	2.6	183.4	82.40	2.995
Year	1988.0	979.55	26.68	3.0	1733.7	886.35	35.885

The precise monthly average system losses, expressed in kW h, are shown in Table 5. The loss in module quality (Mod Qual) is 793.19 kW h per year. The annual mismatch loss (Mis Loss) for modules is 572.95 kW h. The annualized ohmic wiring loss (Ohm loss) is 14,814 kW h. EArrMPP is 51,017 kW h/year for the array's virtual energy at the maximum power point. The total annual inverter loss is 2670.4 kW h.

The balances and key outcomes of a solar system that is connected to the grid are shown in Table 6. The average annual global horizontal irradiation is 1,988 kW h/m^2. On the collector plane, there is a total incident energy of 1733.7 kW h/m^2 per year. The electricity available at the PV generator's output is 1,988 kW h/m^2. About 48.35 MW h of electricity was added to the grid. The ambient temperature is 26.68°C on average.

The PR of incident energy for each month of the year is graphically depicted in Figure 4. The PR on average is 0.775.

Figure 5 represents the incident energy in the plane of the collector. The overall incident energy is 1733.7 kW h/m^2. The incident beam in the collector plane is 940.7 kW h/m^2.

The transposition factor is shown in Figure 6. The worldwide incident energy on the collector plane divided by horizontal global irradiation is known as the transposition factor. For our website, the transposition factor is 1.

The entire system loss diagram for our placer is shown in Figure 7. The total horizontal irradiation is 2,034 kW h/m^2. The collection plane has an effective irradiation of 1,969 kW h/m^2. So, 3.2% of the energy is lost. Solar energy is then transformed into electrical energy by the PV cell. The nominal energy table is 2,001 MW h after PV conversion.

The PV array's efficiency under standard test conditions is 15.35%. A 1,618 MW h of virtual grid energy was obtained. After the inverter is lost, there remains 1,523 MW h of energy left in the inverter's output. As a

Table 5: Detailed system losses – PVsyst simulation

Month	ModQual (kW h)	MisLoss (kW h)	OhmLoss (kW h)	EArrMPP (kW h)	InvLoss (kW h)
January	81.51	58.88	61.58	5,232	258.6
February	67.01	48.40	46.33	4,306	212.0
March	70.12	50.65	44.74	4,509	228.6
April	58.75	42.44	32.37	3,723	212.4
May	51.98	37.54	23.29	3,352	197.0
June	47.98	34.66	19.54	3,097	185.9
July	51.61	37.28	22.30	3,329	189.3
August	57.93	41.85	28.48	3,734	205.5
September	65.39	47.23	39.44	4,207	219.1
October	77.10	55.69	52.76	4,954	243.2
November	80.92	58.45	60.88	5,194	250.1
December	82.89	59.88	65.01	5,317	268.6
Year	793.19	572.95	496.70	51,017	2670.4

Table 6: Balance and main results – PVsyst simulation

Month	GlobHor (kW h/m^2)	DiffHor (kW h/m^2)	T_Amb (°C)	GlobInc (kW h/m^2)	GlobEff (kW h/m^2)	Earray (MW h)	E_Grid (MW h)	PR
January	167.9	88.63	27.63	180.3	175.6	5.232	4.973	0.766
February	148.6	85.18	27.97	147.4	143.1	4.306	4.094	0.771
March	170.8	92.72	28.17	153.8	148.6	4.509	4.281	0.773
April	163.7	77.95	27.43	128.3	122.8	3.723	3.571	0.773
May	163.4	80.45	27.40	113.2	107.2	3.352	3.155	0.774
June	162.6	73.18	25.58	103.9	97.6	3.097	2.911	0.778
July	169.2	73.43	24.93	111.2	104.8	3.329	3.140	0.785
August	167.3	82.78	25.33	124.3	118.6	3.734	3.528	0.788
September	167.2	75.96	25.76	141.7	136.2	4.207	3.988	0.782
October	174.6	85.71	26.50	168.4	163.1	4.954	4.711	0.777
November	167.0	81.36	26.33	177.7	172.9	5.194	4.944	0.773
December	165.6	82.20	27.20	183.4	178.9	5.317	5.050	0.765
Year	1988.0	979.55	26.68	1733.7	1669.3	51.017	48.346	0.775

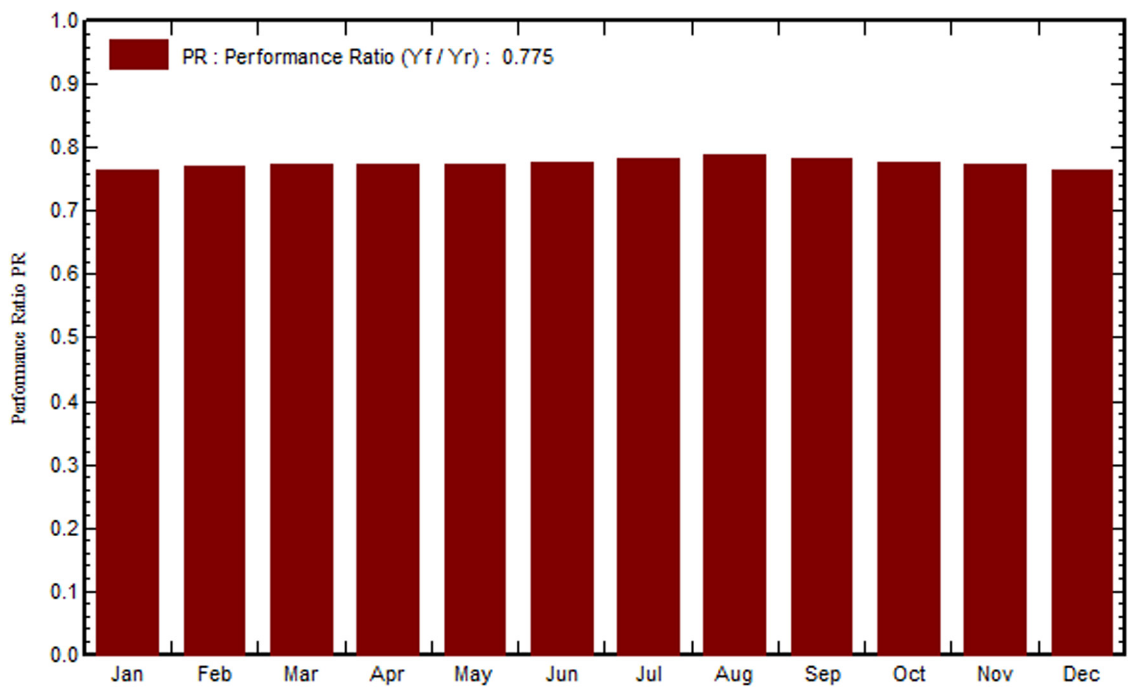

Figure 4: PR–PVsyst simulation.

result, 1,523 MW h of energy was injected into the system (Figure 8).

2.4 Wind system specifications

The wind turbine for electricity generation is an electromechanical device for converting kinetic energy from wind into electricity. Wind energy represents the second source of electricity of renewable origin after hydro, with a capacity that reached globally nearly 722 GW by the end of 2020 [44]. In Morocco, the installed wind power capacity reached 1,405 MW in the same year [45]. The literature abounds with mathematical models of wind generation. For most of these models, the wind speed is required as input. The power curve of wind turbines is defined as the power output of the machine as a function of the wind speed at the hub height. In the current work, a simplified linear model available in the literature is used to estimate the energy produced by the wind. The probabilistic power output of the wind turbine is as follows [46–49]:

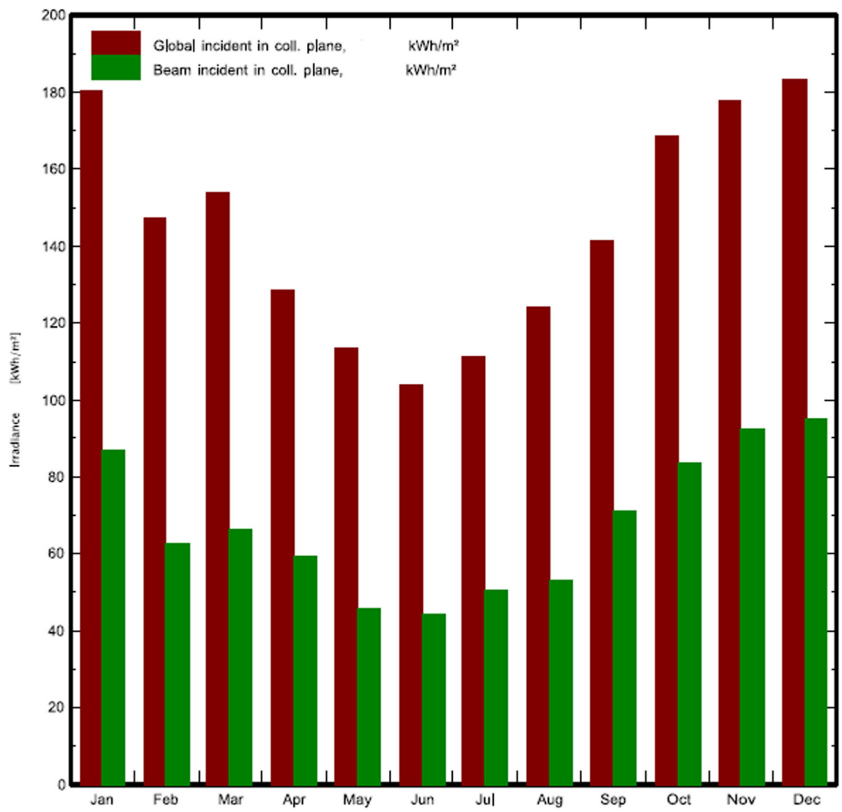

Figure 5: Incident energy.

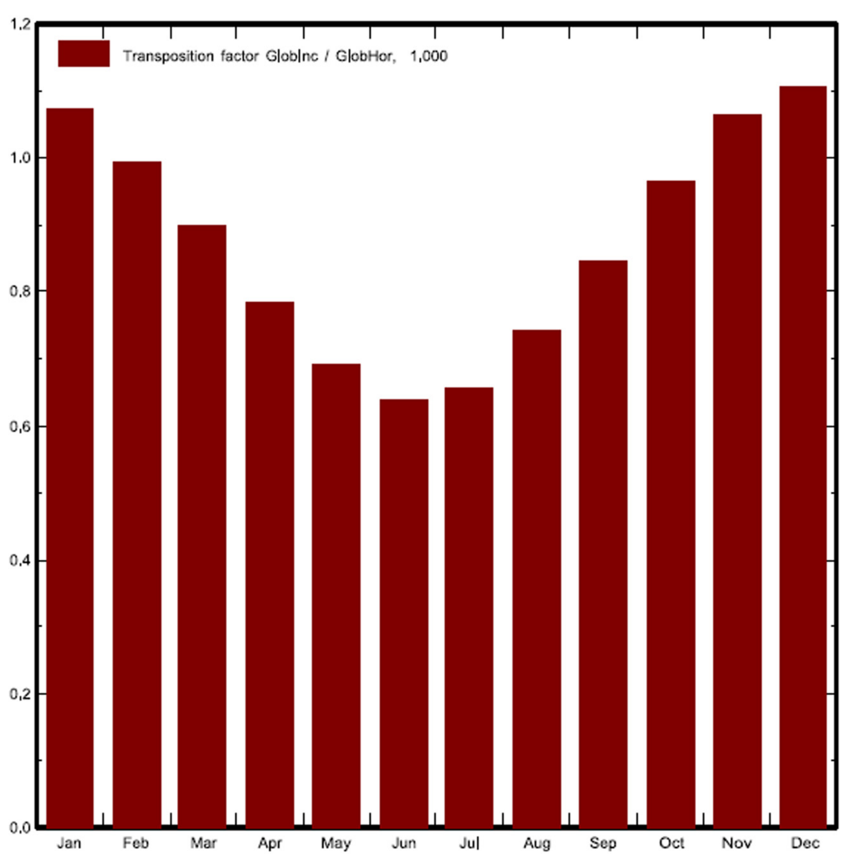

Figure 6: Transposition factor.

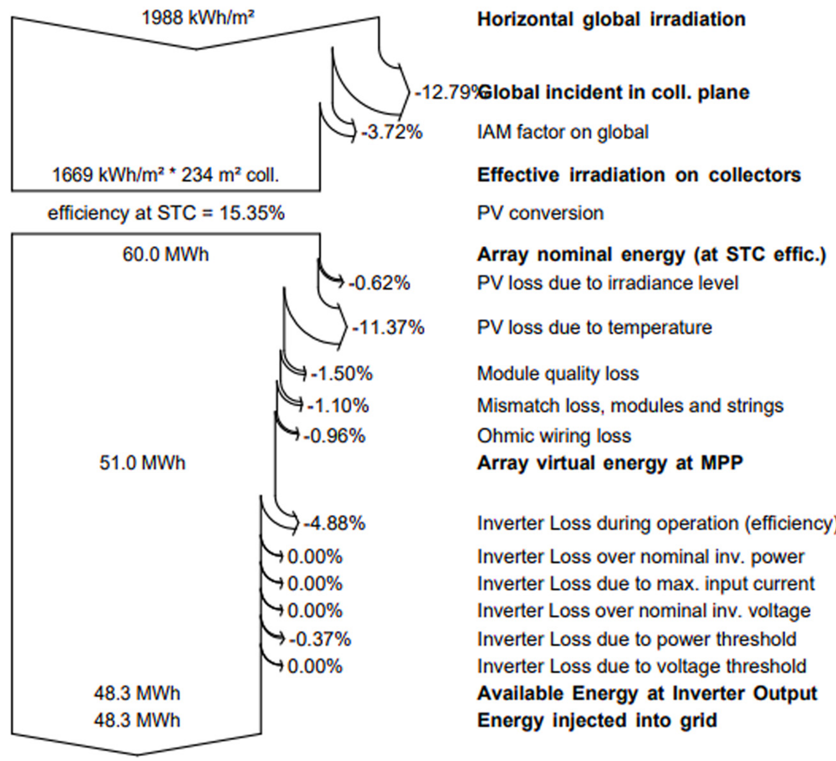

Figure 7: Global system loss.

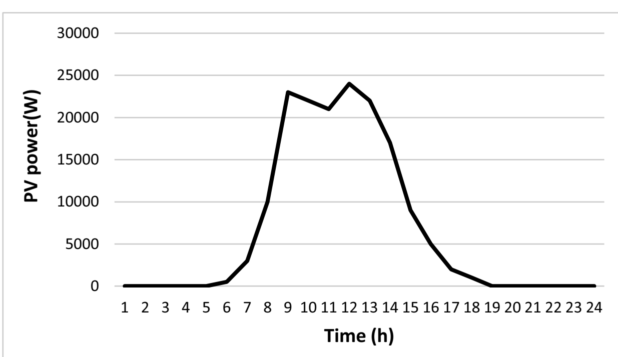

Figure 8: Power *versus* time.

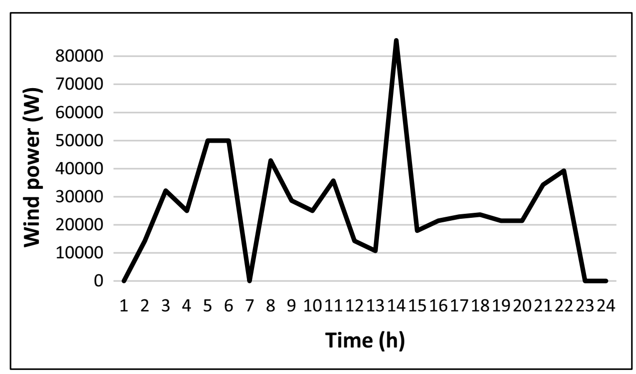

Figure 9: Power produced by an installation of three wind turbines (W).

$$u_w = \begin{cases} 0 & v_{\text{wind}}(t) < v_c \\ P_w(A_w + B_w v_{\text{wind}}(t)) & v_c \le v_{\text{wind}}(t) \le v_r \\ P_w & v_r \le v_{\text{wind}}(t) \le v_f \\ 0 & v_{\text{wind}}(t) > v_f, \end{cases} \quad (2)$$

$$\begin{cases} A_w = \dfrac{v_c}{v_c - v_r} \\ B_w = \dfrac{1}{v_r - v_c}. \end{cases} \quad (3)$$

Figure 9 shows for a typical day, the evolution of the power of the wind turbine with the following characteristics.

Table 7: Technical data of the wind turbines

Wind turbine	Nominal power (kW)	Starting speed	Nominal speed	Cutting speed
PERFEO-5000	5,000	3	10	16

Three PERFEO-5000 wind turbines were selected to provide 15.000 kW of power for an estimated 34% coverage (Table 7).

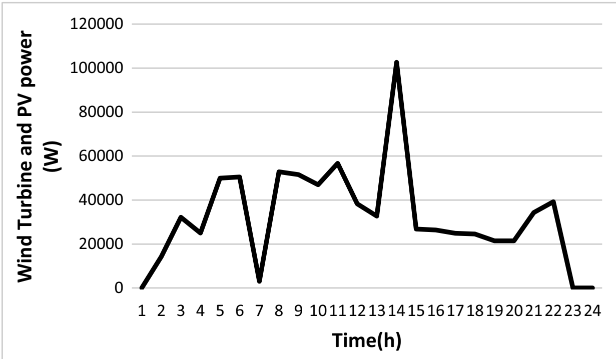

Figure 10: Total renewable energy power generation.

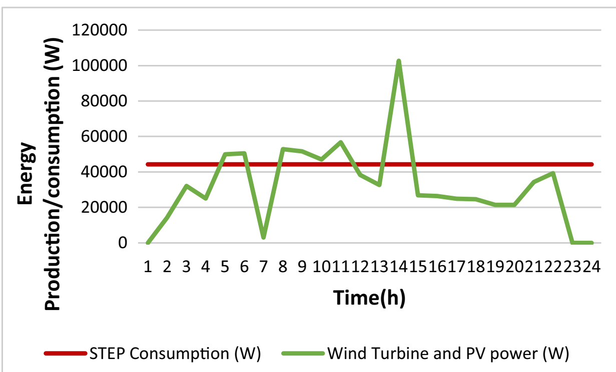

Figure 11: Profile of energy production/consumption.

Figure 9 also shows the production curve of our wind system for wind conditions on an average day in the year 2022 on Metronome.

3 Results and discussions

Our simulations established on the PVsyst software show that the proposed PV system produces an average of 159.50kW h/day. In contrast, the chosen wind system produces an average amount of energy 616.43kW h/day.

Thus, we obtain total renewable energy power generation curve as shown in Figure 10.

Given that the analyzed WWT plant records an energy consumption of 1061.76 kW h/day. Our production/consumption profile is shown in Figure 11.

According to Figure 11, we can say that, thanks to our wind/PV installation, we will be able to reach an electrical coverage of 72% of the energy needs of our WWTP. In fact, we can note that we will have a self-generated energy consumed of 764.41 kW h/day with a surplus blocked or reinjected on the distribution network of 11.52 kW h/day. If this solution is implemented, the electricity costs related to the supply of the WWTP will decrease by 72% compared to the costs of the conventional network. That is to say, savings of more than 3,204.52 euros monthly and thus a reduction of 0.53 euro on each m^3 of water produced by our WWTP. In addition, we will be able to avoid 203.7 tons of CO_2 eq per year.

4 Conclusions

The aim of this article is to reduce the electrical consumption needs of the Ibn Tofail WWTP through its coupling to a PV and wind power installation connected to the grid, with respective powers of 36 kWp and 15 kW. In this sense, a design and then a technical dimensioning have been carried out through mathematical calculations and software of the two sub-installations, namely, our PV field of 120 monocrystalline series/parallel modules with a unit power of 300 Wp and our wind power system of 3 wind turbines of 5 kW power each.

The superposition of the wind and solar production curves with the consumption profile of the water treatment plant informed us about the self-consumption rate, which reached 72%, and about the savings in dirhams and CO_2 expected to be realized by our solution. Thus, we could estimate a reduction of 0.53 euro on each m^3 of water produced by the WWTP and thus 106.76 euro on the 200 m^3 produced daily by the station. It should be noted that the surplus of energy produced *via* our PV/wind turbine solution does not exceed 1.48% of the total production obtained, thanks to the dimensioning we have recommended. However, a configuration that opts for greater coverage in PV production is possible since the surplus can be injected into the buildings closest to the station and will therefore allow for a greater reduction in the overall bill of the university. This is due to the significant electricity consumption of other teaching buildings during the day.

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