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Article

Evaluating HOMER Software's Decision-Making Capabilities in Terms of Ecological Impact and Financial Benefits

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Abstract: The need to protect the environment against human-induced pollution is no longer to be demonstrated. Radical solutions are expected soon to mitigate the impact of climate change in the first step and then gradually improve the ecological situation in the second step. Several efforts on the part of governments and the scientific community are being deployed to better serve the planet. It is in this sense that this work is registered to bring a contribution to this field of study. What it is particularly intriguing about this work is its critical examination of a well-known software, aiming to underscore a significant finding that has been corroborated by multiple simulations even before this study. These simulations reveal that the so-called "best" proposals generated by the software are not as environmentally friendly as one might expect. While these solutions may be economically advantageous, they often fall short in terms of environmental sustainability. The primary aspiration for this work is that, through certain modifications to the algorithms, the platform can introduce a separate option. This option would cater to individuals who are more concerned with environmental respect, allowing them to take advantage of the benefits offered by the platform alongside those who prioritize profit. This work draws inspiration from a recently published paper titled "Ecological impact due to the implementation of a modeled and optimized hybrid system." In comparison to the previous work, this current study provides a wealth of additional details and aspires to make available to the general public a method that stands as a post-Homer study, while offering solutions tailored to those whose concerns lean more towards the well-being of our planet than financial gains.

Keywords: hybrid system; sizing optimization; green energy sale; Homer software; greenhouse gas

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I. Introduction

Solving the energy [1,2] dilemma which opposes, on the one hand, providing the need for energy to everyone, which has become vital in some areas [3], and on the other hand, reducing greenhouse gases to avoid an inevitable catastrophe, is becoming the focus of the most important scientific research nowadays [4]. One thing is sure, the resolution of this dilemma will not come with a snap of the fingers but with sacrifices especially of economic nature. For example, China will have to do without the biggest world reserve of coal to the profits of energies said green [5]. The change, as we well understand, requires a lot of effort and will go through many stages before a satisfactory result for the environment. This work, which is part of one of these transitional stages, come to contribute to the efforts already made by scientists around the world.

The main goal of this study is to make clear the ecological contribution of green solutions [6], here a hybrid system[7] , to show the importance of such action for the planet earth [8]. However, not all hybrid solutions contribute in the same way. Indeed, if the ecological aspect is not taken into account, the results of the optimization, will not be necessarily the best for the environment, and this is exactly what will be demonstrated for the case study of this work, and more precisely during the manipulation of the HOMER software. The conducted study will also determine what is best for the

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climate in our project by defining the best possible combinations of energies that contribute to avoiding the most greenhouse gases.

II. Method

In this section, the choice of the location of the project will be justified. This location was not chosen trivially, but because it has a large solar and wind field throughout the year. Through this section, HOMER [9] will optimize the hybrid system. Other solutions for the optimization of hybrids systems can be used but HOMER has been chosen. This is justified by the fact that this software [10] is very efficient and widely used by scientists.

A. Situational setting

We want to build a new factory of prefabricated building materials (bricks, pipes...). However, being a fervent supporter of ecology, the owner requires that his new factory is as environmentally friendly as possible [11,12]. This plant is running 24 hours a day, so only a hybrid solution [13] can meet the man's requirements.

1) Geographic data

The factory in question is located in Diabat, in the region of Essaouira, Morocco as shown in Figure 1. The factory covers an area of 12 hectares. Five areas cover this surface, namely:

- ⌘ Factory A: Brick manufacturing
- ⌘ Factory B: Manufacture of reinforced concrete pipes
- ⌘ Plant C: Manufacture of polyethylene pipes
- ⌘ External area
- ⌘ Administrative area

Figure 1. Mapping the Diabat area, Essaouira, Morocco.

2) Meteorological data

In this region, the summers are quite hot and arid while the winters are cool and clear on the whole. The climate is windy throughout the year. The following figures give an idea of the weather in Essaouira.

➢ Profile of the temperature

Figure 2 below shows the temperature profile for this region. The temperatures were taken for the period between 1/11/2021 and 1/11/2022, i.e., one year. Note that these data are taken from the NASA website.

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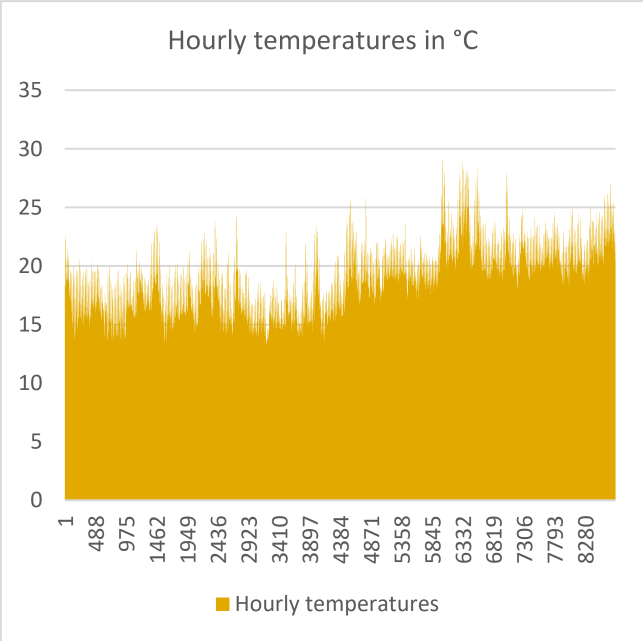

Figure 2. Hourly temperature profile for a full year.

➢ Wind pattern

Figure 3 below shows the hourly wind speed profile at 10m above ground level for the study area. The period of record is from 01/11/2021 to 01/11/2022. In this case, NASA is the source of these samples.

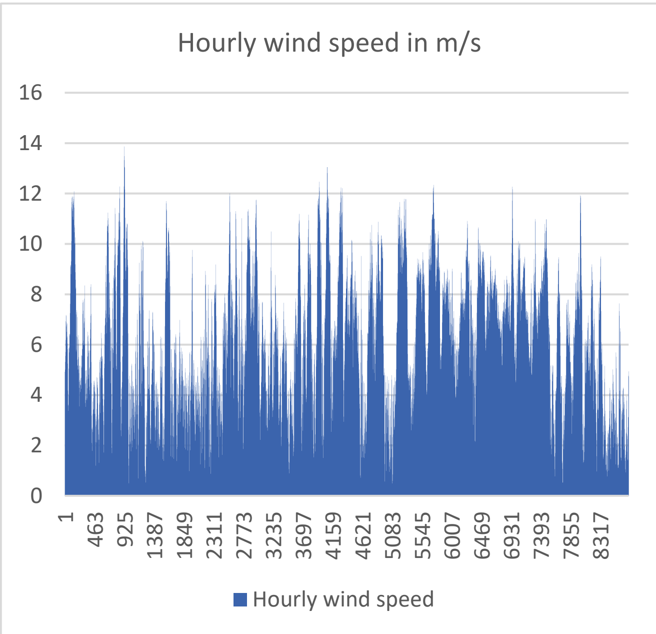

Figure 3. Hourly wind speed profile for a full year.

➢ Solar irradiation profile

Figure 4 below shows the hourly solar irradiation for the study area. The period of record is from 01/01/2021 to 01/01/2022. In this case also, the NASA is the source of these samples.

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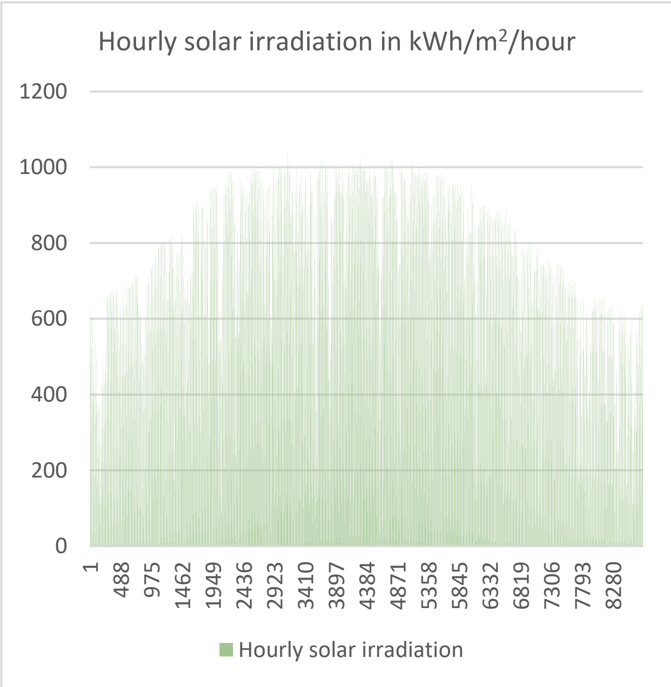

Figure 4. Hourly solar irradiation profile for a full year.

3) Consumption profile

The operating hours of the five areas differ, since plants A and B operate for 12 hours from 7am to 7pm, the plant C operates continuously, i.e., 24 hours a day, the outdoor area operates from 6pm to 6am, while the administrative area has service hours from 8am to 4pm. These data give the following consumption profile [14,15]. This profile is illustrated in Figure 5.

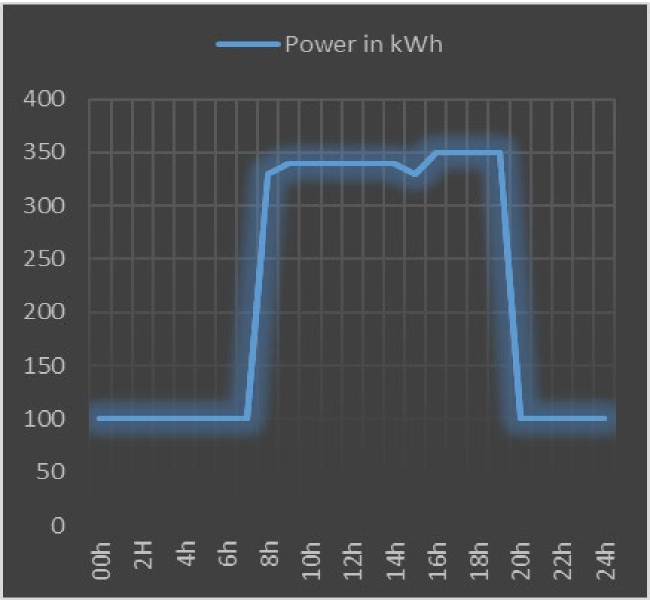

Figure 5. Electricity consumption profile.

B. Optimization of the hybrid system

In this part, the optimization of the hybrid system [16] will take place. The components of this system have been carefully selected. The characteristics of these elements will be exposed in the following.

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1) *Technical characteristics of the elements of the system*

⌘ Wind turbine: For this component, the choice fell on the wind turbine XANT L-33 [330kW], the diameter of its rotor is 33m, the wind turbine power curve is shown in Figure 6 below, and its life span is at least 20 years, while the price of this turbine is 750000 USD.

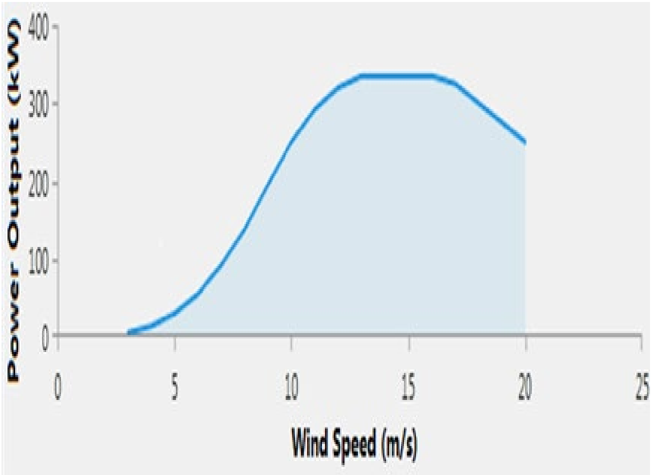


Figure 6. The wind turbine power curve.

⌘ Photovoltaic panels: The Italian brand PEIMAR was preferred for this element, the chosen model is the SG370M which is composed of 72 cells of monocrystalline type, its nominal output (Pmax) is 380W, the module efficiency is 19,07%, its life span is 30 years, its I-V characteristic for different radiations is shown in Figure 7. Note that it costs 640USD for a kilowatt-hour.

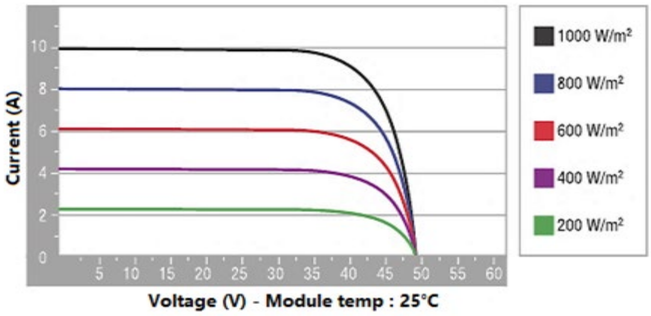


Figure 7. I-V characteristic of the photovoltaic generator for different radiations.

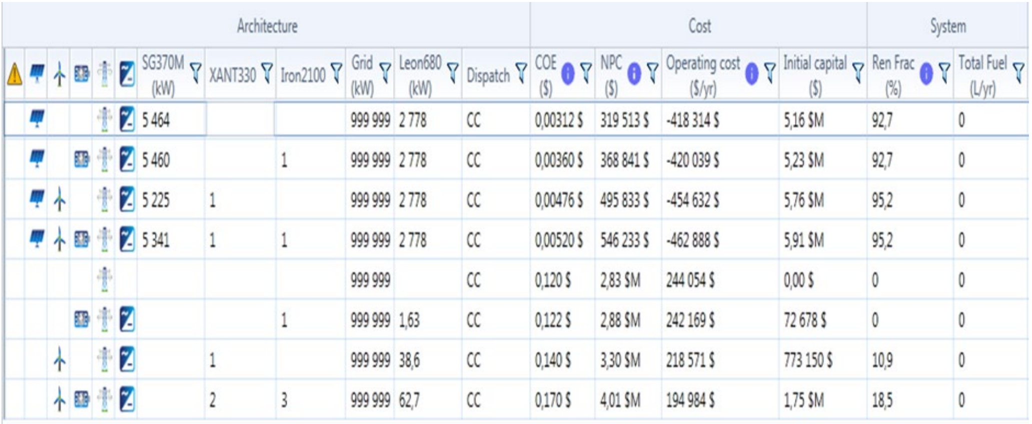
⌘ Storage: Iron Edison LFP 2100Ah was chosen, it's a Lithium iron Battery, its nominal voltage is 48V, its nominal capacity is 101kWh, its life span is 10 years and it costs 71700USD per unit.

⌘ Grid: The public electricity distributor is here the O.N.E.E affiliated with the Moroccan state, the purchase of 1kWh costs 0.12 USD while the sale of 1kWh costs 0.08 USD (assumption for this study since the sale of electricity is still not allowed in Morocco).

⌘ Converter: The chosen inverter is the Leonics GTP-518HET(P) 680Kw, it's a PV-dedicated, three-phase, grid-connected, and it has an integrated MPPT, which is generally dictated by one of three well-known algorithms among them the perturbation and observation (P&O) whose algorithm, AC output 680Kw, output 380V_AC, lifetime assumed to be 10 years and it cost 600USD/kW.

2) HOMER simulation

The optimization [17,18], as we have already mentioned, will be executed by the software HOMER, as it is the best tool for hourly evaluation of hybrid and renewable electricity production systems in the world - without exception. Right after project simulation [19], we obtain as expected a multitude of proposals, more exactly 8 considered as the best as shown in Figure 8. The solutions are ranked from the best economic solution that we note P1 to the least good that we note P8.



Architecture						Cost				System	
SG370M (kW)	XANT330	Iron2100	Grid (kW)	Leon680 (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)
5 464			999 999	2 778	CC	0,00312 $	319 513 $	-418 314 $	5,16 $M	92,7	0
5 460		1	999 999	2 778	CC	0,00360 $	368 841 $	-420 039 $	5,23 $M	92,7	0
5 225	1		999 999	2 778	CC	0,00476 $	495 833 $	-454 632 $	5,76 $M	95,2	0
5 341	1	1	999 999	2 778	CC	0,00520 $	546 233 $	-462 888 $	5,91 $M	95,2	0
			999 999		CC	0,120 $	2,83 $M	244 054 $	0,00 $	0	0
		1	999 999	1,63	CC	0,122 $	2,88 $M	242 169 $	72 678 $	0	0
	1		999 999	38,6	CC	0,140 $	3,30 $M	218 571 $	773 150 $	10,9	0
	2	3	999 999	62,7	CC	0,170 $	4,01 $M	194 984 $	1,75 $M	18,5	0

Figure 8. Optimal solutions proposed by HOMER from P1 to P8.

The Homer software is, de facto, highly proficient in its function, which is to propose solutions that highlight the optimal combinations of hybrid systems based on the user's choice of system types. This choice typically depends on the geological and climatic conditions of the installation sites for the hybrid system. However, from an ecological and responsible standpoint, does this software guarantee its users that these proposals are indeed the best? The answer is "No." Throughout this next paragraph, we have demonstrated this, thereby providing a post-Homer analysis that allows those who prioritize the ecological future of the planet over potential economic gains to find the solution that best suits them.

3) Amount of CO2 avoided

The goal of this part is to be able to extract the solution that allows us to avoid the greatest amount of CO2. Table 1, which has as sources the AMEDE and the GIEG, provides important information about the CO2 emission [20,21]of each type of energy source. These energies can be renewable as well as fossil fuels.

Table 1. Quantity of CO2 emissions for each energy source.

Sources of energy	**CO_2 emissions per kWh**
Onshore wind turbine	*12.7g*
Offshore wind turbine	*14.8g*
Fossil gas	*490g*
Coal	*820g*
Photovoltaic solar	*43.9g*
Oil	*510g*
Hydraulic	*43g*
Concentrating Solar	*22g*

The first step to determining the amount of CO2 avoided is to determine the carbon footprint of the CO2 avoided by each of the proposals and to extract by then the highest value. Table 2 below gives the contribution of each energy source for one kWh in Morocco.

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Table 2. Contribution of each energy source for one kWh in Morocco.

Sources of energy	Contribution to the production	Emission contribution in one kWh produced
Coal	*67.6%*	*554.32*
Oil	*1.5%*	*7.65*
Onshore wind turbine	*11.6%*	*1.47*
Fossil gas	*11.8%*	*57.82*
Hydraulic	*3.2%*	*1.37*
Concentrating Solar	*4.3%*	*0.946*

After calculation, the carbon footprint of a Kilowatt-hour of electricity produced in Morocco is: 623.58g/kWh. Table 3 below summarizes the amount of energy produced in detail from each of the 8 proposals.

Based on these figures, it will be possible to determine the amount of CO2 avoided by each of the proposals and to extract by then the highest value.

Table 3. Amount of energy produced per year in detail from each of the 8 proposals.

	Solar energy production in kWh	Wind power production in kWh	Grid purchases in kWh
P1	*9 977 598*	*0*	*644 029*
P2	*9 978 072*	*0*	*644 026*
P3	*9 656 199*	*731 560*	*436 493*
P4	*9 870 781*	*731 560*	*435 518*
P5	*0*	*0*	*2 033 780*
P6	*0*	*0*	*2 033 780*
P7	*0*	*731 560*	*1 811 995*
P8	*0*	*1 463 121*	*1 658 227*

By calculation, it turns out that P4 is the proposal that avoids the most CO2 with more than 6440 tons/year.

III. Results and Discussion

As the first result of this study, we notice that HOMER [22], although it is a software program oriented towards the promotion of green energy [23,24], does not propose as the first choice the solution that allows the most CO2 to be avoided. In fact the first solution proposed by the software avoids 6185 tons/year of greenhouse gases as opposed to 6440 tons/year for the solution found previously, which is a difference of 255 tons/year which constitutes no less than 5100 tons for the life

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of the project, which is a gigantic figure. To push the study even further and to shed light on this highly rated software, the next step will be the calculation of the cost price of a ton of CO_2 avoided, this calculation will be made in Table 4 below.

Table 4. Calculation of the cost price of a ton of CO2 avoided.

	Investment in USD (A)	The potential financial gain in USD (B)	(A) – (B) in USD	Amount of CO2 avoided over the life of the project in tons	The cost price of one ton of CO2 avoided in USD
P1	*6 788 695*	*10 272 938*	*-3 484 243*	*123 708.2*	*-28.16*
P2	*6 860 560*	*10 342 459*	*-3 481 899*	*125 017.5*	*-27.85*
P3	*7 427 400*	*11 056 980*	*-3 629 580*	*126 331.6*	*-28.73*
P4	*7 573 406*	*11 261 474*	*-3 688 068*	*128 807.4*	*-28.63*
P5	*0*	*0*	*0*	*0*	*0*
P6	*72677*	*0*	*72677*	*0*	*0*
P7	*796 338*	*0*	*796 338*	*31 536.2*	*25.25*
P8	*1 790 336*	*0*	*1 790 336*	*38 556.4*	*46.43*

We note that this qualitative study reinforces the quantitative study already conducted. Indeed, this ecological-economic study does not give an advantage to the best solution proposed by the software but, on the contrary, puts the first four solutions on an equal footing, with even a slight advantage for the last three. Indeed, as the previous table shows, the price to avoid one ton of CO2 is higher for the first software proposal. It can be said then that to carry out a rigorous ecological study, a post-HOMER study is necessary to obtain results that are more beneficial to the environment.

Figure 9. Cash flow of the chosen solution.

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Conclusion

During this study, it was shown that a significant amount of greenhouse gases can be avoided if the choice of the hybrid system used is appropriate. This choice, as we have seen, is not automatically delivered by the HOMER software, Indeed, it has been demonstrated that this well-known software does not allow to obtain the best results ecologically speaking and a posterior study is mandatory. This said and although this work is undoubtedly important it remains only a fraction of the submerged part of the iceberg, and without a real will to change, nothing would be possible, thus and for the good of the planet, a global energy plan should be put in place as soon as possible, and this will also involve the design of more environmentally friendly software or the improvement of existing software, these efforts on the part of scientists around the world will undoubtedly help to achieve a more rapid change. To be indifferent to the current climatic situation is in fact to neglect the future of the generations to come, these last ones will find themselves despite them being in a very critical situation.

Although this solution is not the best economically, its financial aspect is not to be neglected, since the cash flow remains very interesting, as shown in figure 10 below. Indeed, by favoring the solution that avoids the most CO2, the project can generate a profit of 3 688 068 USD over 20 years, which is a very important sum. So we notice that we can help the planet and at the same time make important financial gains. These sums put at stake can be a source of motivation for potential investors.

Ethics approval and consent to participate: The ethical responsibilities of the authors have been taken into account, and the authors therefore declare compliance with all ethical considerations taken into account by the journal. The study has been applied to an imaginary plant to illustrate a situation, plus the study uses data open to the general public, so no consent or approval is needed from any party.

Consent for publication: The authors give their consent for the publication of all personal information & their research work.

Competing Interests: The authors declare no conflict of interest.

Author contributions: Othmane Echarradi: Conceptualization, Methodology, Formal analysis and investigation, Writing - original draft preparation, Writing - review and editing, Resources. Mounir Fahoume: Supervision.

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Availability of data and materials: Most of the data used in this study are either generated by the software used in this study, i.e. HOMER software, or for the rest of the data used they are widely available on the Internet in several websites

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