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Assessment of renewable energy sources to generate electricity for remote areas, South Iraq

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ABSTRACT

With the rising need for utilizing renewable energy instead of traditional energies in electricity generation across the world, a broad assessment of these energies' performance is required to make the most of them everywhere. This paper looks at the techno-economics of renewable energy resources for a distant health clinic in a rural location of southern Iraq. Cost, dependability, and availability are the parameters that were considered in this study, which took into consider the power load in this scenario. Because of its efficacy, the particle swarm optimization (PSO) technique was chosen for the suggested study. Results showed that the respective optimal values for number of photovoltaics (NPV) equal to (10), number of wind turbines (NWT) equal to (5), and number of batteries (NBT) of (33), cost of energy (COE) of (0.518 US$/kWh), loss power supply probability (LPSP) of (0.073%), reliability (REL) of (99.927%) and renewable factors (RF) of (100%) with (66 %) solar energy penetration, and (34%) wind energy penetration. Finally, it was discovered that implementing a hybrid renewable energy system (HRES) is an effective way to address the electrical demands of remote rural regions in Iraq and other developing countries with similar climates.

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NOMENCLATURE

PSO	: Particle swarm optimization	NBT	: Number of batteries
COE	: Cost of energy	IC	: Initial capital cost
NPC	: Net present cost	i	: Real interest rate
LPSP	: Loss of power supply probability	W	: Inertia weight
REL	: Reliability	$C_1 = C_2$	: Cognitive and social parameters

RF	: Renewable factor	NPOP	: Number of populations
NPV	: Number of photovoltaics	N-Ite	: Number of iterations
NWT	: Number of wind turbine	NGB	: Number of global best

1. INTRODUCTION

Currently, the world is seeing a growth in the consumption of energy, which is largely reliant on conventional energy sources, but producing electricity with the use of such standard energy sources causes an increase in the danger of adverse impacts like pollution, greenhouse gas emissions, and global warming. Those issues and challenges have prompted several governments throughout the world to consider alternative energy sources that are based on natural renewable energies [1]–[3].

Iraq, similar to other nations, is seeing an increase in the consumption of energy as a result of energy demand and rising population, prompting the government to establish new plans to use renewable energies as a primary energy source in the future. Iraq enjoys varied and good weather, with high solar radiation and moderate wind speeds [4], [5]. In Iraq, renewable energy sources such as solar panels photovoltaic (PV) and wind turbines (WT) are rarely used, despite earlier researches showing that combining several resources yields an economic system [6], [7].

Various researches focused on hybrid system sizes, yet the ideal configuration is dependent on a number of factors, including weather, location, and a variety of specifications [8], [9]. Utilizing a smart algorithm particle swarm optimization (PSO), this research examines the techno-economic assessment regarding several renewable energy sources for a health center in a southern rural location. Furthermore, the study intends to determine the size of an economic hybrid system that uses solar panels (PV), wind turbines (WT), and batteries (BT), allowing for the discovery of energy skills and resources in such areas.

The remainder of the research is structured as: section 2 provides a full explanation regarding the site's load energy demand, geographic location, and renewable energy possibilities. Section 3 indicates the system components of hybrid renewable energy system (HRES) as well as the various combinations that can be made depending on the rated power and major criteria. Section 4 present technical and cost-effective, whereas sections 5 and 6 present the discussion, results, and conclusion with simulation results and system design.

2. METHODS AND MATERIALS

2.1. Selected site and resource descriptions

A small isolated rural clinic in AL-Faw, Iraq, was selected for feasibility evaluation in the presented work. Figure 1 shows the location of AL-Faw in southern Iraq, close to Kuwait borders [10]. The city is situated at a latitude of 29°56.5'N and a longitude of 48°26.4'E [11]. There is no grid connection in this location.

Diesel generators are presently being used to electrify the health facility. NASA surface meteorological database 2022 [12] was used to obtain data on solar radiation and wind speed. As indicated in Figure 2, the average yearly solar radiation has been 5.57 kWh/m^2/d. As indicated in Figure 3, the average yearly wind speed was 4.49 m/s.

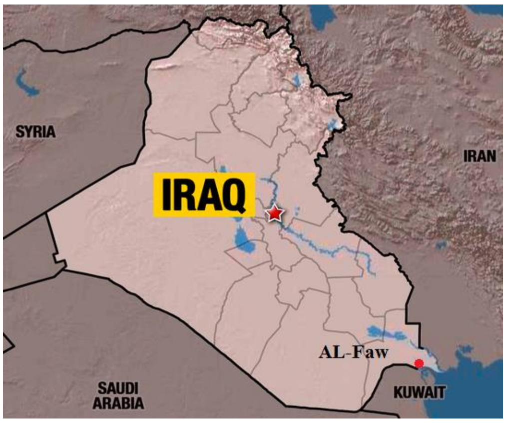

Figure 1. Geographical location of AL-Faw

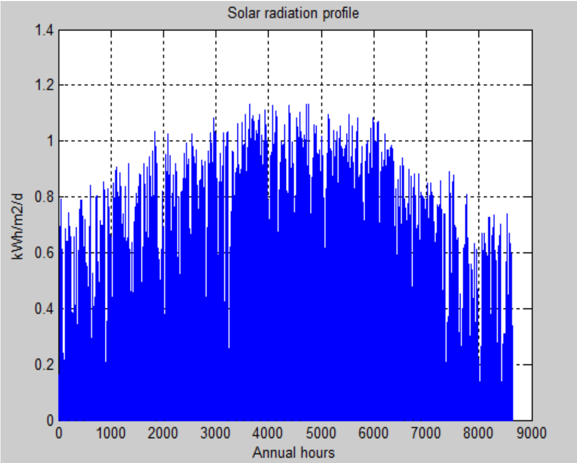

Figure 2. Annual hourly solar radiation

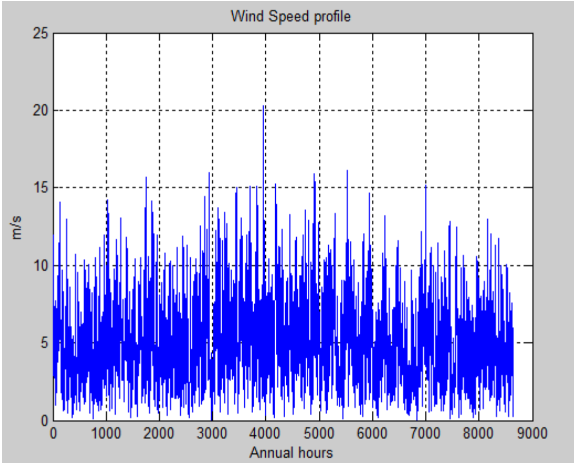

Figure 3. Annual hourly wind speed

2.2. Analysis of the clinic's load

AL-Faw isn't connected to the national grid for electricity [13]. Small pharmacy, waiting room, doctor's office, nurses' room, restroom, treatment room and administration room are all located in the clinic building [14]. Table 1 summarizes the needed power consumption for medical equipment, lights, and other clinic devices. The average annual daily energy need in such clinic is around 31.54 kWh/d, according to load information data [13]. From 4 p.m. to 8 a.m., there is a little load for exterior lighting and a few indoor devices, but most of the load takes place between 8 a.m. and 4 p.m. Figure 4 depicts the load profile.

Table 1. Energy requirement of a typical clinic in AL-Faw

N	Load equipment	Quantity	Power (watts)	Time of use (h)	Energy required (W/h)
1	Vaccine refrigerator	1	350	24	8,400
2	Light bulbs	5	20	12	1,200
3	Oxygen concentrator	1	100	8	800
4	Microscope	1	20	6	120
5	Water heater	1	500	3	1,500
6	Radio	1	30	4	120
7	Vaporizer	1	350	4	1,400
8	Centrifugal nebulize	1	500	4	2,000
9	TV set	1	100	8	800
10	Ceiling fan	4	100	8	3,200
11	Air conditioning	1	1,500	8	12,000
	Total Average daily load				31.54 KWh/d

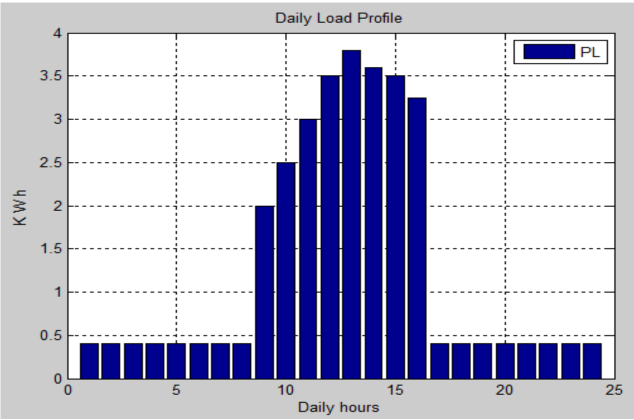

Figure 4. Hourly load profile

3. UNIT SIZING OF HRES

The suggested hybrid renewable energy system (HRES) model is used to construct a PV/WT hybrid system with batteries for storing electricity as well as maintaining a continuous flow of electricity to satisfy demands. Based on the annual hourly mean resource (PV/wind) statistics, the hybrid system's optimum component sizes and techno-economic analysis are calculated [15], [16]. The loss of power supply probability (LPSP) approach is used to assess reliability. The best hybrid system configuration is determined by the system's lowest cost of energy (COE). In the case when available renewable energy is not enough to fulfill load demands, a dispatch technique is necessary to govern the battery bank's (BB) operation [17].

Solar and wind energy are the primary sources of energy for the suggested hybrid system for the health clinic. The main components regarding the system architecture are PV panels, wind systems, and battery units. In relation to solar radiations and temperature, solar panels generate direct current electricity [6]. Through the use of an electric generator, wind energy is turned to electrical energy. Wind turbine energy is primarily dependent on interactions between the wind and the rotor [5], [18]. Also, the battery might store a specific amount of electricity and could only be charged and discharged so many times before it is damaged [9]. The converter is one of the most important components of a hybrid system, transforming electricity that has been generated by PV units to AC electricity and in addition to that, converting the excess AC into DC for storage in the battery in an event of a power outage [7], [19].

A list of numerous components for this project has been produced based on the products accessible on the Iraqi market, and their prices were collected from different manufacturers and sales agents. Thus, the most appropriate and best components have been selected, considering their maintenance and operating qualities, capital costs, lifetime, and any variation costs as shown in Table 2. Each system component has its own distinct configurations, along with prices for replacement, capital, and maintenance. Solar panels (PV), wind turbines (WT), and batteries (BT) are all required components of the hybrid system for ensuring a constant supply to the load. Table 2 shows the specs of the solar panels, wind turbines, batteries, and converters [20].

Table 2. Details of parameters

Parameters	Unit	Value	Parameters	Unit	Value
PV			O&M cost	Unit/y	10
Initial cost	$/kW	1,250	Rated power	kWh	1
Replacement cost	$/kW	1,250	Life time	year	10
O&M cost	Unit/y	10	Converter		
Rated power	Watts	1,000	Initial cost	$/kW	500
Life time	year	25	Replacement cost	$/kW	500
Wind			O&M cost	Unit/y	10
Initial cost	$/1.5 kW	2,000	Rated power	Watts	1,000
Replacement cost	$/1.5 kW	2,000	Life time	year	15
O&M cost	Unit/y	60	Economic parameters		
Rated power	Watts	1,500	Real interest	%	4
Life time	year	20	W		0.5
Battery			$C_1 = C_2$		1
Initial cost	$/kWh	500	NPOP		1
Replacement cost	$/kWh	500	N-Ite		100

4. PARTICLE SWARM OPTIMIZATION ALGORITHM

Particle swarm optimization (PSO) can be defined as a metaheuristic algorithm which is inspired by the social behavior of animals such as fish and birds. Each one of the particles is defined by its velocity and placement, which are both set to zero at the start of each iteration and changed every iteration to discover the best fitness within the search space. The best global fitness might be global or local, and determining the best global involves a comparison of each iteration [8], [20]–[25].

5. RESULTS, AND DISCUSSIONS

The presented study is focusing on the economic optimization regarding the hybrid renewable energy system (HRES) using particle swarm optimization (PSO) with an objective function to minimize cost of energy (COE) and loss of power supply probability (LPSP) production of hybrid renewable energy system (HRES) that include solar panels (PV), wind turbines (WT), and batteries (BT), while considering various constraints, such as the system's optimal sizing for each one of the components, renewable energy factor and meet the electrical demands with high-reliability. The average annual daily energy usage for a load profile is around (31.54 KWh/d). The hybrid micro-grid system's (HMGS) power management technique was implemented to ensure an uninterrupted power supply in various operation modes based on load demands. Particle Swarm Optimization algorithm was created using MATLAB software. All data and variables for the location which concerned hybrid systems and renewable energy sources, like solar radiation, wind speed, solar panel size, battery and wind turbines available, location coordinates, project lifetime, all price details like initial costs, replacement costs, maintenance and operating cost, and hybrid power system component numbers, have been inserted. Solar panels (PV), wind turbines (WT), and batteries (BT), were all optimized via particle swarm optimization. Table 3 shows the best possible solutions. Figure 5 also shows the yearly energy generated as a fraction of total energy via PVs and WTs. The number of populations in the presented work is one, and the swarms motion in 100 iterations for each population is graphically depicted in Figure 6. Given that the optimum combinations are selected at a number of points in the objective domain with the same fitness value, yet differing layouts, designing such systems might be a complicated and difficult.

Table 3. PSO results

N	Station		Results
1	Number of Photovoltaics	NPV	10
2	Number of Wind turbines	NWT	5
3	Number of batteries	NBT	33
4	Cost of energy	COE	0.518 $/KWh
5	Loss power supply probability	LPSP	0.073 %
6	Reliability	REL	99.927 %
7	Renewable factor	RF	100 %
8	Number of global best	NGB	83
9	Photovoltaic production	PV %	66 %
10	Wind turbine production	WT %	34 %

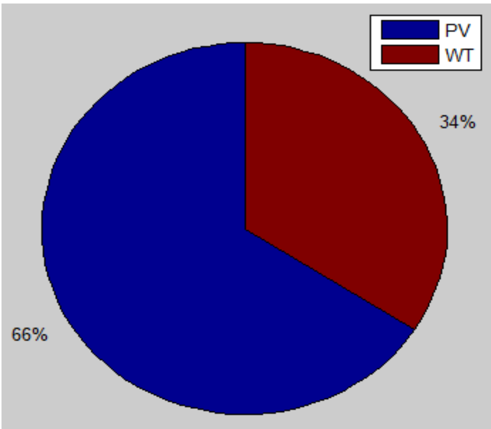

Figure 5. PSO simulation process for 100 iterations

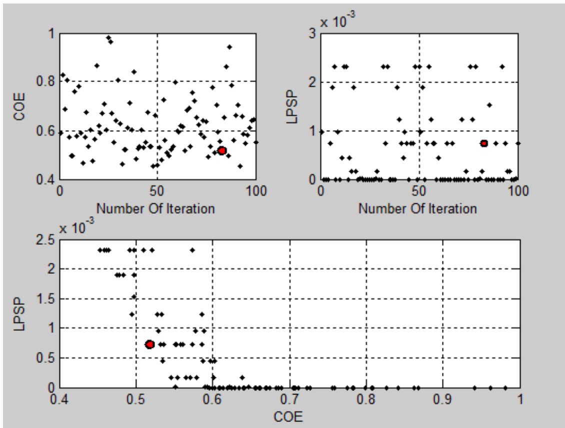

Figure 6. Annual percentage of energy provided by PV and WT

6. CONCLUSION

In today's world, having access to electricity is still a basic community demand. Electrification could improve citizens' lives by increasing access to healthcare and education, whereas also boosting the region's economy. To find the best component sizes and system mixes, researchers used the multi-objective particle swarm optimization (MOPSO) approach. Cost of energy (COE) and loss of power supply probability (LPSP) are also considered objective functions. MATLAB was used to program the suggested approach. The project will last for 20 years. This work tackled the economic problem of minimizing the energy costs of a stand-alone hybrid renewable energy system (HRES) project while taking into account several constraints, like the high efficiency, high dependability, and future expansion. The best results in the research region for NPV (10), NWT (5), NBT (33), COE (0.518 US$/kwh), LPSP (0.073%), Reliability (99.927%), and renewable factors (100%) were achieved with (66%) solar energy penetration and (34%) wind energy penetration. The findings demonstrated that the modified particle swarm optimization algorithm is exceptionally capable of solving objective functions for any difficult and nonlinear situations, as well as finding a global solution, and that it combines multiple factors. Iraq intends to meet its energy requirements entirely through the use of renewable energy sources. Iraq's rich environment explains the country's proclivity for developing and evaluating those systems, which benefit from both wind speed and good solar irradiation. The focus of future work will be on evaluating new hybrid micro grid energy systems in the areas under investigation, as well as renewable energy in other parts of Iraq.

REFERENCES

[1] M. A. Destek and A. Aslan, "Disaggregated renewable energy consumption and environmental pollution nexus in G-7 countries," *Renewable Energy*, vol. 151, pp. 1298-1306, 2020, doi: 10.1016/j.renene.2019.11.138.

[2] M. S. Heyine, A. M. Yahya, D. H. Daher, L. Gaillard, C. Menezo, and A. K. Mahmoud, "Performance evaluation of 50MWp solar plant under different climatic conditions," *International Journal of Power Electronics and Drive Systems*, vol. 13, no. 1, pp. 561-575, 2022, doi: 10.11591/ijpeds.v13.i1.pp561-575.

[3] M. S. Nazir, A. J. Mahdi, M. Bilal, H. M. Sohail, N. Ali, and H. M. N. Iqbal, "Environmental impact and pollution-related challenges of renewable wind energy paradigm – A review," *Science of The Total Environment*, vol. 683, pp. 436-444, 2019, doi: 10.1016/j.scitotenv.2019.05.274.

[4] I. M. Saeed, A. T. Ramli, and M. A. Saleh, "Assessment of sustainability in energy of Iraq, and achievable opportunities in the long run," *Renewable and Sustainable Energy Reviews*, vol. 58, pp. 1207-1215, 2016, doi: 10.1016/j.rser.2015.12.302.

[5] A. S. Darwish, S. Shaaban, E. Marsillac, and N. M. Mahmood, "A methodology for improving wind energy production in low wind speed regions, with a case study application in Iraq," *Computers & Industrial Engineering*, vol. 127, pp. 89-102, 2019, doi: 10.1016/j.cie.2018.11.049.

[6] K. Sudarsan and G. Sreenivasan, "PV solar farm as static synchronous compensator for power compensation in hybrid system using Harris Hawks optimizer technique," *International Journal of Power Electronics and Drive Systems*, vol. 13, no. 1, pp. 554-560, 2022, doi: 10.11591/ijpeds.v13.i1.pp554-560.

[7] S. Kharoubi and L. El Menzhi, "Diagnosing multiple short circuit switches faults in wind turbine doubly-fed induction generator," *International Journal of Power Electronics and Drive Systems*, vol. 13, no. 1, pp. 547-553, 2022, doi: 10.11591/ijpeds.v13.i1.pp547-553.

[8] N. Alshammari and J. Asumadu, "Optimum unit sizing of hybrid renewable energy system utilizing harmony search, Jaya and particle swarm optimization algorithms," *Sustainable Cities and Society*, vol. 60, no. 102255, 2020, doi: 10.1016/j.scs.2020.102255.

[9] V. Suresh, M. Muralidhar, and R. Kiranmayi, "Modelling and optimization of an off-grid hybrid renewable energy system for electrification in a rural areas," *Energy Reports*, vol. 6, pp. 594-604, 2020, doi: 10.1016/j.egyr.2020.01.013.

[10] Z. W. J. Al-Shammari, M. M. Azizan, and A. S. F. Rahman, "Feasibility analysis of hybrid system for a health clinic in rural area, south-eastern Iraq," *Proceedings of the 11th National Technical Seminar on Unmanned System Technology*, pp. 1193-1202, 2019, doi: 10.1007/978-981-15-5281-6_84.

[11] Z. W. J. AL-Shammari, M. M. Azizan, A. S. F. Rahman, and K. Hasikin, "Flexible hybrid renewable energy system design for a typical remote city in Iraq: A case study," *AIP Conference*, vol. 2339, no. 1, 2021, doi: 10.1063/5.0044277.

[12] Homer Pro, "NASA surface meteorology and solar energy database," [Online] Available: www.homer pro.com, 2022.

[13] Z. W. J. Al-Shammari, M. M. Azizan, and A. S. F. Rahman, "Grid-independent pv-wind-diesel generator hybrid renewable energy system for a medium population: A case study," *Journal of Engineering Science and Technology*, vol. 16, no. 1, pp. 92-106, 2021.

[14] Z. W. J. AL-Shammari, M. M. Azizan, and A. S. F. Rahman, "Green micro-grid based on PV/WT hybrid system for remote and rural population in Iraq: A case study," *Intelligent Manufacturing and Mechatronics*, pp. 1081-1093, 2021, doi: 10.1007/978-981-16-0866-7_96.

[15] E. S. Soliman, H. A. El-halim, and A. Refky, "A proposed an interactive reliable aggregated photovoltaic cell for a longer time solar energy extraction," *International Journal of Power Electronics and Drive Systems*, vol. 13, no. 1, pp. 537-546, 2022, doi: 10.11591/ijpeds.v13.i1.pp537-546.

[16] C. Bahanni, M. Adar, S. Boulmrharj, M. Khaidar, and M. Mabrouki, "Performance comparison and impact of weather conditions on different photovoltaic modules in two different cities," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 25, no. 3, pp. 1275–1286, 2022, doi: 10.11591/ijeecs.v25.i3.pp1275-1286

[17] L. H. Fang and R. B. A. Rahim, "Design of Savonius model wind turbine for power catchment," *Int. J. Electr. Comput. Eng.*, vol. 12, no. 3, pp. 2285–2299, 2022, doi: 10.11591/ijece.v12i3.pp2285-2299.

[18] D. Muddenahalli Narasimhaiah, C. K. Narayanappa, and G. S. Lakshmaiah, "Hybrid controller design using gain scheduling approach for compressor systems," *Int. J. Electr. Comput. Eng.*, vol. 12, no. 3, p. 3051, 2022, doi: 10.11591/ijece.v12i3.pp3051-3060.

[19] R. F. Idan, A. J. Mahdi, T. Mohammed, and A. Wahhab, "Optimized proportional-integral controller for a photovoltaic- virtual synchronous generator system," *International Journal of Power Electronics and Drive Systems*, vol. 13, no. 1, pp. 509-519, 2022, doi: 10.11591/ijpeds.v13.i1.pp509-519.

[20] Z. W. J. Al-Shammari, M. M. Azizan, and A. S. F. Rahman, "Feasibility of pv-wind-diesel hybrid renewable energy power system for off-grid rural electrification in Iraq: A case study," *Journal of Engineering Science and Technology*, vol. 16, no. 3, pp. 2594-2609, 2021.

[21] N. Ghorbani, A. Kasaeian, A. Toopshekan, L. Bahrami, and A. Maghami, "Optimizing a hybrid wind-PV-battery system using GA-PSO and MOPSO for reducing cost and increasing reliability," *Energy*, vol. 154, pp. 581-591, 2018, doi: 10.1016/j.energy.2017.12.057.

[22] A. M. Abdelshafy, H. Hassan, and J. Jurasz, "Optimal design of a grid-connected desalination plant powered by renewable energy resources using a hybrid PSO–GWO approach," *Energy Convers. Manag.*, vol. 173, no. May, pp. 331–347, 2018, doi: 10.1016/j.enconman.2018.07.083.

[23] H. Borhanazad, S. Mekhilef, V. Gounder Ganapathy, M. Modiri-Delshad, and A. Mirtaheri, "Optimization of micro-grid system using MOPSO," Renew. Energy, vol. 71, pp. 295–306, 2014, doi: 10.1016/j.renene.2014.05.006.

[24] M. S. Nazir, A. J. Mahdi, M. Bilal, H. M. Sohail, N. Ali, and H. M. N. Iqbal, "Environmental impact and pollution-related challenges of renewable wind energy paradigm – A review," *Sci. Total Environ.*, vol. 683, pp. 436–444, 2019, doi: 10.1016/j.scitotenv.2019.05.274.

[25] V. Suresh, M. Muralidhar, and R. Kiranmayi, "Modelling and optimization of an off-grid hybrid renewable energy system for electrification in a rural areas," *Energy Reports*, vol. 6, pp. 594–604, 2020, doi: 10.1016/j.egyr.2020.01.013.

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