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A Comparative Study on the Use of Energy Systems In Agricultural Production and Financing Methods: A Case Study of Wheat In The New Valley

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Abstract: Worldwide attention has been increasingly directed towards the use of renewable energy, with solar energy being one of the most important sources. Due to Egypt's geographical advantage with high solar radiation, the state has shown interest in the New Valley Governorate in recent years to boost the agricultural sector, particularly wheat production, contributing to overall development and food security. The research problem lies in the high costs of irrigation using traditional energy systems, forming around 35-40% of production costs in the Wadi region. Given the state's efforts to reduce the wheat food gap, expanding into desert lands has become essential. However, high irrigation costs contribute to increased production expenses and reduced returns for farmers. The research aims to understand the impact of different energy systems on wheat irrigation, including diesel, electricity, and solar cells. It analyzes production situations, production costs, and economic returns in the Republic and the New Valley, using both descriptive and quantitative analysis methods. The research revealed that the New Valley is strategically located in the Western Desert, covering about 44% of Egypt's total area. The governorate relies on groundwater for irrigation, with approximately 3,150 million m^3 available. Wheat cultivation occupies 58% of the cultivated area in the New Valley, emphasizing its importance. Regarding the financial indicators for establishing a solar power station with a capacity of 107.25 KW in the study areas, the net present value of costs and revenues was 49,76.6 thousand dollars, at a discount rate of about 18%. The net present value was around $27,300, with a benefit-to-cost ratio of about 1.55%, a higher internal rate of return of about 32%, and a payback period of 4.8 years. The return of investment was approximately 18.01%, aligning with the discount rate, confirming the economic viability of solar energy projects. The positive financial evaluation criteria recommend expanding and implementing such projects.

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Introduction:

Most countries around the world are facing severe crises due to reliance on non-renewable energy in economic activities. This has led to price disruptions, especially after the Russo-Ukrainian crisis, exacerbating hardships, especially for developing nations. Consequently, there has been a growing global interest in using renewable energy as a strategic option for achieving desired sustainable development. With traditional energy sources (coal, petroleum, and gas) depleting and their prices rising globally, coupled with increased greenhouse gas emissions (constituting around 26% of total emissions from fossil fuels), the shift to clean or renewable energy systems has become inevitable. This is essential to ensure resource sustainability, preserve the global climate, and meet energy needs while achieving desired economic growth.

Solar energy stands out as a vital and effective source of renewable energy for achieving sustainable development. Egypt's geographical advantage, being located in the solar belt, positions it to expand the utilization of solar energy as an environmentally safe and economically affordable alternative to fossil fuels. Egypt benefits from strong solar radiation, reaching up to 12 hours daily in summer and a minimum of 8 hours daily in winter. Consequently, the country has initiated various future projects aimed at harnessing solar energy and replacing traditional energy sources, (Abo El-Naja,2018).

In recent years, there has been an increased focus on the New Valley Governorate to expand agricultural land due to its vast arable areas and the availability of necessary water from the underground reservoir. The agricultural sector in the New Valley is considered promising and can play a significant role in comprehensive development, particularly in wheat production, contributing to food security. The region not only possesses essential elements for agricultural production but also leads in solar brightness percentage nationwide, receiving direct sunlight exceeding 10.7 KWh/m2 and experiencing over 4000 hours of sunlight annually,(Mostafa,2020).

Research Problem:

Within the framework of the Egyptian government's efforts to achieve sustainable development programs in all sectors, in harmony with the 2030 development strategy, and to reduce reliance on traditional energy sources, where the agriculture sector accounts for about 20% of energy consumption in Egypt. The cost of energy represents about 15-18% of the total agricultural production costs in the Delta region, while it exceeds 35%-40% in the New Valley and desert lands. Given the state's efforts to reduce the wheat food gap, which reaches about 50%, expanding into desert lands has become necessary. Due to the reliance on wells for irrigation in the New Valley Governorate, the high costs of irrigation increase production costs and reduce returns for farmers. Therefore, the research aims to study different energy systems and estimate their impact on production costs.

Aim:

The research focuses on estimating the impact of different energy systems used in irrigating wheat crops, represented by diesel, electricity, and solar cells. It analyzes the simulated impact on the income of farmers and the state. This involves studying the production situation of wheat in the Republic and the New Valley, examining production costs and economic returns in the study sample based on different energy systems. The research also estimates the inflows and outflows from establishing a solar energy station in the New Valley region and evaluates its financial criteria, as well as assessing the project's sensitivity to risks and uncertainties, And identifying financing opportunities available for expansion of solar energy.

Method and Data sources:

The research relies on two data sources: secondary data collected from the Economic Affairs Sector, the Directorate of Agriculture in the New Valley, and the Agricultural Administration in the Dakhla Center. Regarding primary data, a field sample was collected from the villages in the Dakhla Center of the New Valley. The sample, selected through systematic random sampling from the records of agricultural units, represents all three energy systems. A questionnaire was designed and distributed, resulting in 105 valid responses.

The research adopts descriptive and quantitative statistical methods to analyze the data and present the results. This includes estimating production costs and economic indicators for wheat production under different energy systems in the study area, using a questionnaire designed for the study's purpose. Financial evaluation criteria are also calculated following methodology for establishing a solar energy station with a capacity of 107.25 KW/hour, Lotfi's (2005).

This involves discounted and undiscounted criteria, The discounted standards it is take into account the time value of the unit of money, which are represented by the benefit-to-cost ratio standard, the net present value standard, and the internal rate of return, Which is reflected in the interest rate on capital, which is estimated at about 18% during the year 2023. The non-discounted standards are estimated “which do not take the time element or the inflation rate into account,” which is represented by the recovery period, and the criterion of the rate of return on investment.

The research assumed that the useful life of solar cells is about 25 years. The annual depreciation installment was estimated according to the straight line method, and this is considered the most common method for calculating the depreciation value, (Abo El-Naja,2022).

1. Annual depreciation installment = cost of the depreciable asset ÷ the useful life of the asset.
2. Salvage value = purchase value of the asset - (the year in which the salvage value is to be calculated x the annual depreciation installment).

The sensitivity of the project was also analyzed in light of low returns or high costs. Sensitivity analysis is defined as the amount of change in the project's commercial profitability measures (present value, internal rate of return) as a result of a change in one or more of the values of the project's specific factors (Sullivan et al., 2002). Cooper (2003) indicated that sensitivity analysis is used to determine the impact of technical and economic factors on the profitability of the project. Or predicting the impact of change in project outputs as a result of changes in input values in light of risk and uncertainty (Jovavic, 1999). These risks may be due to increased investment costs for production factors, or decreased revenues as a result of increased supply.

Results:

1. Study Area Characteristics:

The New Valley Governorate occupies a prominent position in the heart of the Western Desert, covering approximately 44% of Egypt's total area, with a land area of about 440.1 thousand km². The governorate comprises 5 centers. The Gross Domestic Product (GDP) of the New Valley Governorate was estimated at around 17 million EGP in the year 2020/2021, equivalent to 0.3% of the total national GDP. The agricultural output value in the New Valley is approximately 8.4 million EGP for the same year, constituting about 49.7% of the governorate's total output. The agricultural output of the governorate represents around 2% of the national output, (Ministry of Planning, 2022). The state aims to develop this region to benefit from its available natural advantages optimally, particularly the water and land resources, which are crucial determinants of agricultural production. The limited water resources, estimated at about 3.5 million acres suitable for agriculture, pose a significant challenge to agricultural development in the New Valley.

a) Water Resources:

The New Valley Governorate relies on groundwater for irrigation, with an estimated available groundwater quantity of around 3,150 million m^3. The annual consumption is approximately 1,887 million m3, indicating that the Dakhla Center accounts for about 38% of the groundwater quantity. The governorate is characterized by a scarcity of rainfall. Table (2) illustrates the distribution of wells and the annual consumption in millions of m^3 for irrigating an area of approximately 508.8 thousand acres. The state supports Dakhla's farmers by providing about 234 wells, constituting approximately 38.4% of the total government wells. The total number of government, investment, and private wells is around 7406, with a consumption volume of about 2.4 billion m3. The number of wells in Dakhla Center is approximately 2334, representing 32% of the total wells in the governorate, with a consumption volume of 400 million m^3. These wells are used to irrigate 84.4 thousand acres, representing about 17% of the governorate's area.

Table (1): Flowing Groundwater Quantity (Million M^3) at the Center Level in 2022.

Centers	Kharga	Paris	Balt	Dakhla	Farafra	Total
Groundwater Quantity	139.5	919	61.5	1200	830	3150

Source: Information and Decision Support Center, Directorate of Agriculture, New Valley Governorate, 2020.

Table (2): **Distribution of wells and the annual consumption volume in (Million M^3) in 2022.**

Centers	Government wells		Investment wells		Local springs		Annual consumpti	Total Agricultural Area (acres)	% of Cultivated Area
	N	Annual consumpti	N	Annual consumpti	N	Annual consumpti			
Kharga	118	86.2	13	4.9	1336	14.6	140.3	39866	%8
Paris	134	67.8	2	1.8	31	0.4	76.9	11207	%2
Balt	51	16.4	24	16.4	834	8.0	40.69	4540.8	%1
Dakhla	234	166.9	284	186	1816	47.3	400.2	84448.2	%17
Awaynat	0	0.0	1887	1223.6			1223.5	196840	%39
Farafra	72	115.6	570	416.2			531.9	171885	%34
total	**609**	**452.9**	**2780**	**1848.9**	**4017**	**70.3**	**2413**	**508787**	**%100**

Source: Information and Decision Support Center, Directorate of Agriculture, New Valley Governorate.

b) Land Resources:

Data from Table (3) indicates the total area of agricultural land and the number of holders in the districts of the New Valley Governorate during the agricultural season 2022/2023. The total agricultural land area reached approximately 1.2 million acres, with around 62% of it cultivated, equivalent to 748 thousand acres. The Farafra district comes as the largest district in terms of cultivated area in the New Valley Governorate with a percentage of 80%. It is followed by the Dakhla district with a percentage of 10%. The cultivated area of both Farafra and Dakhla districts represents about 64% and 10%, respectively, of the total agricultural land area. The cultivated area in the New Valley Governorate is estimated to be about 62%, representing investment opportunities for agricultural expansion in the region.

The average number of holders for both Farafra and Dakhla districts indicates that the average holding for each investor or farmer is approximately 74.5 and 5.9 acres, respectively. Due to the state's interest in small investors, considering them the backbone of Egyptian agriculture and the target of modern agricultural technology transfer, and also due to the ease and accuracy of data, dealing with small investors was easier. Thus, the Dakhla district was chosen. In addition to the diversity of irrigation systems in the district, following the three systems, while the rest of the districts rely on electricity and submersible irrigation, solar-powered irrigation, or a hybrid between the two systems.

Table (3): Total Agricultural Land Area and the Number of Holders for the districts of the New Valley Governorate during the agricultural season 2022/2023.

Centers		Total Area	Total Cultivated	% Cultivated	% Cultivated of Total Valley	Total Bore Area	Holders Count	Average Area per Holding	Wheat	
									Area in Acres	% of Total Cultivated Area
Kharga		50420	37905	%75	%5	12515	10126	3.7	6983	%18
Paris		47028	13607	%29	%2	33421	1639	8.3	3869	%28
Balt		57103	24706	%43	%3	32397	3382	7.3	10767	%44
Dakhla	Mowt	**64518**	**43817**	%6	%6	**20701**	**8628**	5.1	**11439**	**%26**
	Qasr	**62293**	**31175**	%4	%4	**31118**	**4580**	6.8	**9462**	**%30**
Awaynat		934095	597017	%64	%80	337078	8101	73.7	393984	%66
Farafra		1215457	748227	%62	%100	467230	36456	20.5	436504	%58
total		**50420**	**37905**	%75	%5	**12515**	**10126**	3.7	**6983**	**%18**

Source: Directorate of Agriculture in the New Valley for the agricultural season 2022/2023.

2. Study of the production situation of wheat crops in the Republic and the New Valley:

According to the data provided in Table (3), the importance of wheat crop in the crop structure of the New Valley Governorate is evident, as it occupies 58% of the cultivated area in the governorate. Due to the strategic importance of the wheat crop as the backbone of Egyptian food security, it was consulted for studying different energy systems in the New Valley Governorate.

Reviewing the data provided in Table (4), which indicates the wheat production volume in the Republic and the New Valley Governorate during the period (2010-2022), it appears that the average wheat area reached approximately 3250, 171 thousand acres, respectively. The wheat area in the New Valley represents about 5% of the wheat area in the Republic. Studying the general trend of area development from Table (5) shows that the growth rate for the Republic and the New Valley reached approximately 0.6% and 10.1% respectively, indicating the available opportunities for expansion in wheat cultivation in the New Valley and the limited expansion in the rest of the Republic due to the presence of clover as a competing crop that hinders expansion in alternative crops. The data also indicate that the area increases annually by about 19.6, 17.2 thousand acres respectively. It is also evident that production increases annually by about 96.5, 49.6 thousand tons respectively. The production growth rate reached approximately 1.1% and 12% respectively, and it is noteworthy that the difference in productivity between the Republic and the New Valley reached about 0.4 tons. Additionally, the productivity increases annually at a rate of approximately 0.5% and 2.2% respectively for both the Republic and the New Valley.

Table (4): Evolution of Area, Productivity, and Production for Wheat in the Republic and the New Valley Governorate during the period (2010-2022)

(Area: 1000 acres, Production: 1000 tons, Productivity: Tons/acre)

Years	Republic			New Valley			% of Area	% of Productivity	% of Production
	Area	Productivity	Production	Area	Productivity	Production			
2010	3001.4	2.39	7169	65.5	1.91	125	%2.20	%1.70	%80
2011	3048.6	2.75	8371	84.3	2.28	192	%2.80	%2.30	%83
2012	3160.7	2.78	8795	103.3	2.24	231	%3.30	%2.60	%80
2013	3377.9	2.80	9460	129.6	2.08	270	%3.80	%2.90	%74
2014	3393.0	2.74	9280	130.6	2.30	300	%3.80	%3.20	%84
2015	3468.9	2.77	9608	197.0	2.08	410	%5.70	%4.30	%75
2016	3353.2	2.79	9343	185.9	2.48	461	%5.50	%4.90	%89
2017	2921.7	2.88	8421	152.4	2.53	386	%5.20	%4.60	%88
2018	3156.8	2.64	8349	184.3	2.38	439	%5.80	%5.30	%90
2019	3134.9	2.73	8559	202.2	2.54	513	%6.40	%6.00	%93
2020	3402.6	2.68	9102	192.3	2.51	482	%5.70	%5.30	%94
2021	3419.4	2.88	9842	254.0	2.71	689	%7.40	%7.00	%94
2022	3417.0	2.82	9623	341.1	2.59	884	%7.40	%7.00	%92
Average	**3250.5**	**2.74**	**8917**	**171.0**	**2.36**	**414**	**%5.0**	**%4.4**	**%86**

Source: Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Agricultural Statistics Bulletin, various issues.

Table (5): General Trend Equations for Wheat Production in the Republic and the New Valley Governorate (2010-2022).

Item		Average	β	T	F	R^2	Growth Rate
Republic	**Area**	3250	19.6	1.5	2.3	0.17	%0.60
	Productivity	8917	96.5	1.96	3.9	0.26	%1.1
	Production	2.74	0.014	1.6	2.5	0.18	%0.50
New Valley	**Area**	171	17.2	7.3	53.6	0.83	%10.1
	Productivity	414	49.6	8.6	73.5	0.87	%12
	Production	2.36	0.05	5.4	29.2	0.72	%2.2

Source: Compiled and calculated from Table (4).

2. **Description of the study sample for Dakhla Center:**

Dakhla has an area of 158.4 thousand KM^2, representing 36% of the total area of the governorate. The cultivated area in Dakhla constitutes about 10% of the cultivated area in the New Valley. Dakhla Center consists of the cities of Mowt and Qasr. The cultivated area in Mowt and Qasr is approximately 64.5 and 62.3 thousand acres, respectively, occupying about 68% and 50% of the total area. The number of holders is around 8.6 and 4.6 thousand holders, with an average holding size of about 5.1 and 6.8 acres per farm. Studying the winter crop structure of Dakhla Center shows that the wheat area represents 26% and 30% of the total area of Mowt and Qasr, respectively, with an area of about 20.9 thousand acres according to the data in Table (3).

To estimate the production costs of wheat according to the energy systems used in irrigation and water pumping from wells, the study sample was selected from the records of the Agricultural Administration in the cities of Mowt and Qasr in the Dakhla Center. The sample consisted of about 105 farms for both cities, distributed in 5 villages with a total area of 350 acres and an average holding size of 3.3 acres. The distribution was based on energy systems, with 35 farms for each of the diesel, electricity, and solar cell systems.

Table (6): Total Area and Number of Participants for the Sample Villages in the Study during the agricultural season 2022/2023.

The Statement	City	Mowt				Qasr		
	Village	**Mowt**	**Al-Rasheda**	**Al-Hindaw**	**Total**	**Al-Muhub**	**West Al-Muhub**	**Total**
Wheat	Acres	4270	1099	850	11439	1190	5930	9462
Total	Acres	17428	4140	2645	43817	3815	20308	31175
Wheat Area	**%**	%25	%27	%32	%26	%31	%29	%30
Study Sample Area	Acres	90	60	50	200	50	100	150
Diesel	Farms	10	5	5	20	5	10	15
Electricity	Farms	10	5	5	20	5	10	15
Solar Energy	Farms	10	5	5	20	5	10	15

Source: Directorate of Agriculture in the New Valley for the agricultural season 2022/2023.

I. **Production Costs:**

By studying the production costs per acre of wheat in the villages of Mowt and Qasr during the agricultural season 2022/2023 through Table (7), it is evident that the average production costs per acre of wheat amounted to approximately \$518, \$419, \$411 for diesel, electricity, and solar energy, respectively. The percentage of irrigation costs with different energy systems is estimated to be about 36%, 23%, 12%, respectively. The rental costs are estimated to be approximately 6%, 13%, 19% according to the system linked to well operation. Thus, the total energy production costs are estimated to be about 43%, 33%, 29%, respectively. This poses a challenge for farmers due to the high energy prices, especially in the face of the unstable global economic conditions. Additionally, the economic liberalization policy adopted by the state, eliminating subsidies on both petroleum and electrical energy, further complicates the situation.

Table (7): Average Production Costs for Wheat in the New Valley Governorate during the agricultural season (2021-2022).

Input	Unit	Diesel				Electricity				Solar Energy			
		Q	p	V	%	Q	p	V	%	Q	p	V	%
Seeds	**kg/acre**	63.7	0.62	39	%8	67.5	0.62	42	%11	65.0	0.62	40	11%
Manure	**M3**	12.5	6.27	78	%15	11.8	5.73	68	%18	12.2	6.47	79	22%
Urea(%46.5)	**kg/acre**	67.5	0.33	23	%4	70.0	0.35	24	%6	74.5	0.33	24	7%
Phosphate	**kg/acre**	95.0	0.29	28	%5	90.0	0.28	26	%7	91.5	0.30	27	8%
Pesticides	**liters/acre**	2.0	3.67	7	%1	1.8	3.67	7	%2	2.2	3.67	8	2%
H labor	**man/day**	11.3	6.67	75	%15	11.0	6.33	70	%19	10.8	6.27	68	19%
Auto labor	**hour/day**	4.5	3.50	16	%3	4.0	3.33	13	%4	3.8	3.33	13	4%
V C irrigation	**hour/day**	17.8	7.06	126	%24	22.6	2.00	45	%12	24.2	0.00	0	0%
F C irrigation	**pounds/acre**	1	63	63	%12	1	45	45	%11	1	51	51	12%
maintenance	**pounds/acre**	1.0	6.67	7	%1	1.0	5.00	5	%1	1.0	3.33	3	1%
Harvest	**hour/day**	1.3	12.57	16	%3	1.4	13.33	19	%5	1.8	13.67	25	7%
Rent	**pounds/acre**	1.0	33.33	33	%6	1.0	50.00	50	%13	1.0	66.67	67	19%
Taxes	**pounds/acre**	1.0	6.67	7	%1	1.0	6.67	7	%2	1.0	6.67	7	2%
Total costs	**pounds/acre**			**518**				**419**				**41 1**	

Source: Compiled and calculated from the field sample data for the agricultural season 2022/2023.

II. Revenues According to Different Energy Systems:

Table (8) indicates the net per-acre return for wheat crop according to different energy systems. The average wheat supply price for the 2022/2023 season was approximately $50 per ton based on purity 22.5, and the average straw price was estimated at about $10 per load. The net per-acre return for diesel, electricity, and solar cells irrigation systems was approximately $242, $383, $394 per ton, respectively. The average productivity was around 13.7, 14.4, 14.5 tons per acre, respectively. The net return per ton was estimated at about $17.7, $26.6, $27.2. Based on the data presented in Tables (7, 8), the economic efficiency of applying solar cell irrigation systems is evident. The average irrigation costs with solar cells decrease by approximately $8, $107 per acre compared to electricity and diesel, respectively. Additionally, the net return per acre increases by about $11, $152, respectively.

Table (8): Revenues for Wheat Crops According to Different Energy Systems in the Study Sample for the Agricultural Season (2021-2022).

System	Main crop			Secondary crop			Total Revenue	Total costs	Net profit
	productivity	Price	Revenue	productivity	Price	Revenue			
Diesel	13.7	50	685	7.5	10	75	760	518	242
Electricity	14.4	50	720	8.2	10	82	802	419	383
Solar Energy	14.5	50	725	8	10	80	805	411	394

Source: Compiled and calculated from the field sample data for the agricultural season 2022/2023.

III. Financial Evaluation of Renewable Energy:

The outputs of summits and conferences held by countries on climate, climate change, and global warming emphasize the need to reduce carbon emissions resulting from burning fossil fuels. Most international reports indicate that by the year 2050, renewable energy will represent about 90% of the energy systems used. Renewable energy is characterized by lower operating costs than diesel electricity. Employment opportunities are expected to increase about three times compared to fossil fuels. Despite one drawback of solar energy being the decrease in brightness during the winter season, this can be overcome by using exchange meters to inject electricity into the public grid and recover it when needed.

IV. Investment Costs for Establishing a Solar Power Station:

Table (9) indicates the investment components for establishing a solar power station with a capacity of 107.25 KW in the study areas. The average investment costs were around 54.2 thousand dollars, where the average price of solar cells accounted for approximately 69.3% of the total investment costs, with an investment value of about $37.5 thousand. The assumed lifespan of these cells is approximately 25 years. The replacement and renewal item comes in second with a value of about $6.16 thousand, attributed to the renewal of Inverter, which is renewed every 10 years, accounting for approximately 11.4% of the total costs. The average price of supports is estimated at about 9.9% of the total investment costs, with a value of $5.36 thousand.

V. Depreciation Value:

The data in Table (10) indicates the total depreciation value for the solar power station, where the depreciation value for the asset is estimated at about 10 thousand dollars. This value is included in the cash flows in the last year of the project's life.

Table (9): Investment Costs for Establishing a Solar Power Station for the Agricultural Season (2022-2023).

Item	Unit	Number	Price	Total	%
Average price of solar cells	$ /W	107250	0.35	37538	%69
Average price of mounts for solar panel installation	$/KW	107.25	50.0	5363	%10
Average price of Inverter	$	1	2333	2333	%4
replacement and renewal	$	1	6160	6160	%11
Average price of wiring and control panel	$	1	1333	1333	%2
Costs of designing panels and labor	$/KW	107.25	8.3	894	%2
Average price of exchange meter between panels & grid	$	1	333	333	%1
Annual rent	$	1	66.7	67	%0
Annual maintenance costs	$	12	10.0	120	%0
Others	$	1	33.3	33	%0
Total	-	-	-	54174	100

• Average exchange rate at the time of estimation: 35 Egyptian Pounds per US Dollar.

Source: Compiled and calculated from the field sample data for the agricultural season 2022/2023.

Table (10): Depreciation Value for the Solar Power Generation Station for the Agricultural Season (2022-2023).

Item	Value	Production life	Estimated life	Depreciation installment	Depreciation value for the asset
Average price of solar cells	37538	25	30	1501.5	7507.5
Average price of mounts for solar panel installation	5363	25	30	214.5	1072.5
Average price of inverter (inverter)	2333	10	15	233.3	1166.7
Average price of wires and junction box	1333	10	12	133.3	266.7
Total	**54174**	**0**	**-**	**2082.7**	**10013**

The source: Compiled and calculated from Table (9).

VI. Revenues for Solar Power Generation:

The data in Table (11) indicates the total annual revenues for a solar power generation station with a capacity of approximately 107.25 KW/hour. The average number of sunlight hours is estimated at around 8 hours daily, considering both summer and winter seasons, totaling 2880 hours during 360 working days (allowing 5 days for annual maintenance). The average price per kilowatt-hour is approximately 0.038 dollars. Thus, the operational value for the station is estimated to be around 11.84 thousand dollars annually.

Table (11): Annual Revenues for Solar Power Generation Station for the Agricultural Season (2022-2023).

	Station Capacity	Operating Hours	Operating Days	Price per Kilowatt/Hour	Annual Revenue Value
Item	**107.25 Kilowatt/Hour**	**8**	**360**	**0.038**	**11840.4**

Source: Website of the Electricity Regulatory and Consumer Protection Agency, Egypt.

VII. Financial Indicators for Solar Power Generation:

Table (12) provides a financial analysis of cash inflows and outflows during the year 2023, along with indicators for discounted and undiscounted financial analysis. The total present value of costs and revenues amounted to approximately 49.76.6 thousand dollars in order, with a discount rate of about 18%. The net present value was estimated at around 27.3 thousand dollars. The benefit-to-cost ratio was about 1.55%, which is greater than one. The internal rate of return was approximately 32%, exceeding the discount rate. The discounted criteria confirm the feasibility of the investment. As for the undiscounted criteria, the payback period results indicate the possibility of recovering the project's capital within 4.8 years from the start of the project. The return of investment rate was about 18.01%, aligning with the discount rate.

Project Sensitivity Analysis:

The results of Table (12) indicate the sensitivity of the project in the case of a 10% increase in costs with stable revenue. The economic feasibility of the project is evident, with a net profitability of about $3.9 thousand. The benefit-to-cost ratio is approximately 1.45%, which is greater than one. The internal rate of return is around 28%, still higher than the current interest rate. The payback period is estimated at about 5.4 years.

In the case of a 10% decrease in revenue with stable costs, the net present value is approximately $19.9 thousand, a positive value. The benefit-to-cost ratio is about 1.4%, still greater than one. The internal rate of return is around 28%, and the payback period is estimated at about 5.5 years.

It is noteworthy that the return of investment rate is approximately 16%, 15.8% in the case of increased costs, a decrease in revenue, respectively, which is lower than the currently declared discount rate. It is worth mentioning that the discount rate during the period (2021-2023) is unstable due to economic conditions and inflation. The discount rate in 2020 was about 9.25%, and it is expected to decrease with economic stability.

VIII. Analysis of the Impact on Farmers and the State:

Undoubtedly, expanding wheat production in Egypt has become a national security concern, especially amid the instability of political and security conditions in Russia and Ukraine, hindering trade flow. Egypt's imports from these countries represent about 80%. Additionally, the continuous depreciation of the exchange rate and the decline in the pound's value against the dollar pose challenges for the state in providing foreign currency.

As the indicative supply price set by the state for wheat is determined based on average production costs, which inevitably rise in the study area due to reliance on groundwater for irrigation. Alternatively, the price is determined based on the alternative cost of crops such as clover and local beans, which generally have prices close to wheat. This prompts farmers to cultivate and replace wheat with these high-yield crops.

Table (12): Presents the results of financial analysis indicators for discounted and undiscounted criteria for the 107.25 KW solar station.

Item			Present Value$	Project Sensitivity Analysis by 10%	
				Increase Costs	Decrease Revenue
Present Value of Total Costs at 18%		PV	48998	53898	48998
Present Value of Total Revenues at 18%		PV	76570	76570	68913
Discounted Criteria	Net Present Value	NPV	27272	3907	19915
	Benefit-to-Cost Ratio	B/C	%1.55	%1.45	%1.4
	Internal Rate of Return	IRR	32%	28%	%28
Undiscounted Criteria	Payback Period	PBP	4.79	5.39	5.46
	Average Return of investment Rate	RRI	%18	%16	%15.8

Source: Compiled and calculated from Table (1) in the appendix.

Therefore, one political tool to increase wheat cultivation area is to reduce production costs. As shown in Table (7), the percentage of irrigation costs with different energy systems was about 36%, 23%, and 12% respectively. Hence, replacing diesel and electric power with solar energy achieves a cost reduction of approximately $138 and $37/acre, respectively. Consequently, it provides additional net profit for farmers in the same amount.

Regarding the state, the total wheat area in the New Valley is estimated to be about 341.1 thousand acres in 2022. Shifting to solar energy as an alternative to diesel and electricity reduces costs by approximately $47.1 and $12.6 thousand, respectively. It also achieves additional net profit for the state in the same amount, according to the results of Table (13).

Table (13): Impact of Simulating the Use of Solar Energy on Wheat Production in New Lands.

Item	The Farmers (Dollars per Acre)			The State (thousand $ / Acre)		
	Present Values	Values after Transformation	Difference	Present Values	Values after Transformation	Difference
Average Production Costs Using Diesel / Acre	518	380	-138	176.7	129.6	-47.1
Average Production Costs Using Electricity / Acre	419	382	-37	142.9	130.3	-12.6
Net Return / Acre Using Diesel	242	380	138	82.5	129.6	47.1
Net Return / Acre Using Electricity	383	420	37	130.6	143.3	12.6

Source: Compiled and calculated from the results of Table (7).

IX. Available Financing Opportunities:

Given the farmers' struggle with the increasing costs of irrigation using traditional energy sources (Diesel-Electricity) and the rise in energy prices, especially amid the unstable global economic conditions, farmers are increasingly interested in using renewable energy. Solar energy, in particular, represents a vital source for crop irrigation. The lack of self-financing for most farmers and the high costs of establishing solar power stations lead to dependence on external financing. This is achieved through:

Loans:

Commercial banks provide loans for establishing solar power stations. The Egyptian Agricultural Bank also offers various financing programs and initiatives to upgrade energy systems with decreasing annual interest rates. This is aimed at encouraging farmers to expand the use of solar energy technology in agricultural projects, specifically within the "Solar-Powered Irrigation Systems Financing." The bank supports projects that upgrade irrigation systems using solar energy, enabling farmers and producers to purchase and install modern solar-powered irrigation pumps. The bank provides financing of up to 80% of the project cost with a simple and decreasing annual interest rate, a repayment period of up to five years. According to the bank, loan amounts start from 50,000 EGP and have a maximum limit of one million EGP. The target beneficiaries include farmers, companies, major investors, and agricultural reform associations.

Carbon Credits:

Carbon credits are financial instruments tradable as an innovative means to address the negative effects of climate change. They are issued to entities implementing projects that reduce greenhouse gas emissions, with the renewable energy sector being a beneficiary of carbon credit issuance. Carbon credits represent a balance that allows a company to emit a certain quantity of greenhouse gases. If a company successfully reduces its greenhouse gas emissions, it accumulates surplus credits that it can sell to other companies, thereby earning money. Egypt has expressed its commitment to addressing carbon emissions at the COP 27 conference in 2022 in Sharm El Sheikh, announcing the establishment of a voluntary market through the Egyptian Stock Exchange for trading carbon emission reduction certificates to contribute to initiatives protecting the environment. These certificates are considered a new addition to the diverse financial instruments in the Egyptian stock market, attracting local and international interest. The certificates are associated with various sectors and industries, such as fertilizers, construction materials, and various activities. The stock exchange aims to facilitate trading procedures in collaboration with securities trading companies and relevant intermediaries to maximize the benefits for investors in the Egyptian stock market.

Leasing Financing:
Some companies establish solar power stations and sell the produced energy. Additionally, certain companies provide leasing financing for solar energy with repayment systems lasting up to seven years using the leasing finance system. A fixed monthly rate is paid regardless of the amount of energy generated by the system each month. The program is designed to consider the seasonal nature of this sector and, consequently, the seasonality of revenues and cash flows for farmers. The leasing program is designed to alleviate cash burdens and remove one of the significant obstacles facing farmers when investing in solar energy systems.

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Appendix:

Table (1): **Financial Analysis of Cash Inflows and Outflows for Solar Power Generation Station in 2023**

year	1	10-2	11	20-12	21	24-22	25	Total
Investment Costs	47894	0	2800	0	3360	0	0	54054
Operating Costs	120	60	60	60	60	60	60	1560
Cash Outflows	48014	60	2860	60	3420	60	60	55614
Cash Inflows	11840	11840	11840	11840	11840	11840	11840	296010
Depreciation Value	0	0	0	0	0	0	10013	10013
Overall Cash Inflows	11840	11840	11840	11840	11840	11840	21854	306023
Net Cash Flow	**-36173**	**11780**	**8980**	**11780**	**8420**	**11780**	**21794**	**250410**

Source: Compiled and calculated from the field sample data for the agricultural season 2022/2023.

12/16/2023