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Harnessing Solar Energy for a Sustainable Future in Iraq

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Abstract: ***Solar energy projects have shown significant global growth in electricity generation. This upward trend is expected to continue because of the increasing affordability and accessibility of solar technologies, accompanied by their low carbon emissions. Although Iraq has ample sunshine duration for harnessing solar energy, the country is still in the early stages of implementing solar energy projects. This study highlights the vital role that sustainable energy sources like solar power can play in providing alternative electricity options while positively impacting climate change mitigation efforts in Iraq. By reducing reliance on fossil fuels and transitioning towards renewable sources like solar energy, we have an opportunity to combat climate change more effectively. In order to tap into the immense potential for solar power, this study examines the impact of solar energy utilization in select government institutions on climate change and carbon emissions in Iraq. A total of (546) existing buildings in Iraq were evaluated for conversion to solar energy. This conversion might yield an average annual energy production of 62353 kw/hr and reduce carbon emissions by 167662 tons annually. The results of this study emphasize the potential for solar power to provide alternative sources of electricity while positively impacting the environment, economy, and overall well-being of Iraq's population. It is imperative for government institutions, businesses, and communities to embrace this renewable energy revolution and work towards a greener future together.***

Keywords: Solar Energy, Greenhouse, Photovoltaic.

1. INTRODUCTION

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Solar energy is essential to a zero-carbon energy transition in the world. National and international policy focused on reducing carbon emissions and increasing electric grid resiliency continue to drive demand for solar (Curtis et al., 2021). Solar panels are commonly used for small-scale applications, such as powering homes, businesses, and other small facilities. Solar energy is one of the most important renewable energies on the planet because it is the main reason for the presence of most other energies on the one hand and its large quantities that can be obtained in various parts of the earth on the other hand (Tsilingiridis & Martinopoulos, 2004). The importance of solar energy lies because it does not cause any environmental problems, as it does not release any pollutants to the atmosphere and the direct use of solar energy, produces very little greenhouse gases, except for the modest amount of carbon dioxide (CO2) emissions produced in the manufacture of conversion devices(Adeeb, 2015). Photovoltaic (PV) cell is the essential unit of a solar energy generation system in which sunlight is promptly converted to electrical energy. These cells are made of semiconducting materials, such as silicon, The solar panel absorbs photon energy and transforms it into electricity through the PV mechanism (Al-ezzi, 2022). In Iraq, focusing on renewable energy potential to enhance energy security, reduce greenhouse gas emissions, and foster economic growth is needed. The utilization of solar power not only aligns with Iraq's commitment to sustainable development but also offers a pathway to a more sustainable and prosperous future.

2. LITERATURE REVIEW

The energy requirement of 60% the world primary energy from 2002 to 2030 increases annually by 1.7% per year (Thu, Vo, Ko, Huh, & Park, 2021). Coal, petroleum, and natural gas are fossil fuels in the form of the present primary sources of energy. Statistics showed that total global carbon emissions are equal to the total for all previous years, with fossil fuel making up more than 80% of the primary energy mix for each energy sector over the past 27 years (Thu et al., 2021). Within the past 30 years, greenhouse gas (GHG) emissions have been increasing, accounting for 60% of the total GHG presently. The percentage of carbon dioxide emissions from coal, gas, and oil is estimated to be 44%, 20%, and 35%, respectively, together with big amounts of other GHG emissions, such as methane and nitrous dioxide (Thu et al., 2021) Iraq faces energy security challenges due to its dependence on oil and gas reserves. While Iraq boasts favorable sunshine duration for solar energy utilization, the country's solar energy projects are still in their infancy. According to the study area from areas of Iraq the amount of solar radiation reaching up to (794.7) (mW/cm2/day(in the summer in the month of June while annual average amount of solar radiation in Baghdad Governorate at 561.5 (mW/cm2/day) (Farej, 2021). Therefore , which of these energies and the availability of potential natural and human and economic cost development. As well as the most environmentally friendly, with the slowdown in the electricity sector in the study area in particular and Iraq in general. Make the first choice for alternative energy source after the crude oil in Iraq is solar energy (Alasady, 2011). Solar power can play in providing alternative electricity options while positively impacting climate change mitigation efforts in Iraq. Implementing solar energy projects at government institutes not only helps reduce their carbon footprint but also sets a powerful example for other sectors and communities within Iraq. Iraq, which is totally dependent on the export of oil, is facing a great danger. This danger is the fluctuation of oil prices and their

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decline in continuous fall, causing pressure on the state budget and preventing the improvement of services. Another great threat to the Iraqi citizen is the polluted air due to emissions resulting from the use of poor types of fuel, both gasoline that is full of lead compounds and diesel with high sulfur content (Al-waeli, Al-asadi, & Fazleena, 2017). Moreover, Iraq is the exploration of oil and gas and its dangerous environmental impacts (Al-aasadi, Alwaeli, & Kazem, 2015). Mitigate this effect, it will be important for Iraq to move forward. Iraq's updated Nationally Determined Contribution (NDC) target a conditional reduction of GHG emissions by 15 percent by 2030, equivalent to 90 million metric tons of carbon dioxide (MMtCO2) per year. The main updates to Iraq's 2021 NDC document have been focusing on reducing the time frame from 2035 to 2030, and placing greater emphasis on eliminating gas flaring and on the displacement of high-carbon liquid fuels by natural gas, especially in power generation (World Bank, 2022). This paper aims to explore the impact of adopting solar energy at various government institutes in Iraq on climate change and carbon emissions reduction and reducing dependence on imported fossil fuels through domestic renewable resources such as sunlight. Thus, the country can enhance its energy security and improve economic resilience.

3. METHODOLOGY

A comprehensive assessment of 546 buildings in Iraq has uncovered significant potential for harnessing solar power, providing detailed simulations and cost estimates for off-grid solar systems that could generate substantial electricity, reduce emissions, and deliver meaningful carbon reduction benefits. The comprehensive assessment of 546 buildings across Iraq has revealed vast potential for harnessing solar power in the region. Conducted in cooperation with the Iraqi Ministries of Higher Education and Scientific Research, Electricity, and Environment, the study used advanced PVSYST7.4 modeling software to provide detailed simulations and cost estimates for installing off-grid solar systems on each building. The assessment examined the feasibility of rooftop solar panel installations, calculating projected installation costs in US dollars for all 546 buildings. It also estimated annual electricity generation capacity in megawatt-hours, anticipated annual emission reductions in tonnes, and the corresponding carbon reduction value in US dollars. This thorough evaluation highlights Iraq's significant opportunity to tap into its abundant solar resources and reduce reliance on traditional, carbon-intensive energy sources. The comprehensive assessment of buildings in Iraq has revealed the vast potential for harnessing solar power in the region. The detailed simulations and cost estimates provided through this study highlight the feasibility and benefits of rooftop solar panel installations, including projected electricity generation, emission reductions, and associated carbon reduction value. This thorough evaluation underscores Iraq's significant opportunity to leverage its abundant solar resources and transition towards more sustainable, cost-effective energy solutions. By utilizing the data and insights from this assessment, policymakers and stakeholders can make informed decisions to drive the widespread adoption of solar power across the country, ultimately reducing reliance on traditional, carbon-intensive energy sources.

4. RESULTS AND DISCUSSION

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An assessment of 546 of existing government Iraqi Building was conducted as shown in Table1.

Table 1: Summary of feasibility studies for the institutions involved in converting their buildings into energy efficient

Number of buildings	**Carbon ireduction in dollars/ year**	**The amount of annual emissions reduction in tons**	**The reduction in the annual electricity lists in dinars**	**Annual energy availability in megaw-att hours**	**Percentage of supplied energy per year**	**New estimated cost in dollars**	**The concerned party**	**T**
2	14400	240	33136800	276.14	26.20 %	320560	Ministry of Commerce/Ministry Headquarters	1
2	18260	304	42026400	350.22	14.00 %	497120	National Investment Authority	2
3	11730	195.5	39105600	325.88	60.00 %	332800	The Iraqi National Olympic Committee building	3
2	27664	461	92160000	768	100.00 %	808500	State Council building	4
2	13852	230.88	46176000	384.8	65.00 %	338280	House of Wisdom building	5
3	47100	785	156960000	1308	45.00 %	1637200	Building of the Presidency of the Supreme Judicial Council	6
2	13320	220	30674400	255.65	70.00 %	229840	Ministry of Youth and Sports/Engineering Department	7
6	46200	770	106363200	886.36	37.88 %	788880	Federal Integrity Commission/Ge	8

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							neral Headquarters	
2	15000	250	34,498,800	287.5	48.00 %	270660	Prime Ministery / Political Prisoners Foundation	9
3	13140	219	30240000	252	18.00 %	340080	Ministry of Immigration and Displacement	10
5	176520	2942	406369940	3386.42	67.84 %	3188400	Sunni Endowment Office	11
3	15739	262.33	36225120	301.876	33.00 %	312080	Supreme Judicial Council/Judicial Institute	12
2	5160	86	11890000	99.13	14.10 %	118400	Prime Ministery/ Board of Advisors	13
1	30330	505.5	67704000	564.2	16.00 %	736800	Ministry of Education / Ministry headquarters	14
1	13782	229.7	31730640	264.422	36.13 %	226084	Scientific Iraqi Academy	15
1	12540	209	28860240	240.5	65.70 %	232160	The Supreme Commission for Accountability and Justice/General Headquarters	16
1	12000	200	27745440	231.212	18.95 %	291000	The Ministry of Labour and Social Affairs	17
1	24336	405.6	56016000	466.8	35.08 %	502120	Ministry of Planning/Ministry Headquarters	18
1	23568	393	54240000	452	18.00 %	405000	Ministry of Construction and Housing	19

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1	22716	378.6	52284000	435.7	83.14 %	413960	General Company for Maritime Transport	20
5	34200	570	78702000	655.85	32.80 %	692160	Ministry of Interior /al-wala Camp	21
7	52980	883	121965600	1061.38	70.33 %	1180000	Wasit Federal Presidency of Appeal (courts 7	22
6	29142	485.7	67072800	558.94	37.59 %	515480	Diwan of the al-shia Endowment/Ima Kadhim -m al College	23
1	31800	31800	73176000	609.8	69.21 %	466260	Ministry of Commerce/General Grain Processing Company	24
1	7370	122.83	16961280	141.344	44.87 %	126560	High Commission for Human Rights / Headquarters	25
1	18000	300	41436000	345.3	19.00 %	426000	Ministry of Higher Education/Educational Complex	26
2	12480	208	28836000	240.3	48.00 %	283680	University of Information and Communications Technology	27
2	6600	110	15,187,200	126.56	68.50 %	140320	Karbala Federal Courts of 2) Appeal (courts	28
1	9762	162	22385280	186.544	100.00 %	186600	Ministry of Commerce/General Company for Grain Trade	29
1	28584	476.4	65784000	548.2	11.54%	561760	Ministry of Health/Ministry Headquarters	30

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5	31380	523	72232800	601.94	78.22 %	694100	Muthanna Federal Courts of Appeal (court5)	31
1	32820	547	75516000	690.3	34.00 %	957500	National Insurance Company / Headquarters	32
2	29838	497.3	68676000	572.3	15.70 %	600740	Baghdad Municipality / Secretariat Office	33
8	52187	869.8	120108000	1001	62.20 %	896000	Din -Salah al Federal Courts of Appeal (Court8)	34
2	6798	113.3	15644400	130.4	31.64 %	78200	Ministry of Interior/Organized Crime Directorate	35
1	11850	197.5	27280800	227.34	99.81 %	166160	Ministry of Transport/General Authority for Meteorology and Seismic Monitoring	36
2	12864	214.4	29607600	246.73	26.56 %	193560	Ministry of Health/Forensic Medicine Department	37
1	24660	411.1	56772000	473.1	35.15 %	426000	Kirkuk Governorate/Governorate Office	38
1	47296	788.27	108852000	907.1	74.20 %	819000	Kirkuk Governorate/Provincial Council	39
3	2370	39.5	5456400	45.47	100.00 %	45560	Kirkuk -Governorate/18 story -class, two school	40
1	1212	20.2	2,792,400	23.27	100.00 %	22680	Kirkuk Governorate /	41

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							th grade 12 school	
1	740	12.33	1702800	14.19	100.00 %	13040	Kirkuk Governorate / th grade school6	42
1	11400	190	26234400	218.62	100.00 %	170740	Kirkuk Governorate/First Real Estate Registration Department	43
1	58656	977.6	134995440	1125	98.82 %	89880	Presidency of the Kirkuk Federal Court of Appeal	44
2	5547	92.46	12768000	106.4	66.43 %	1007500	Kirkuk Governorate/Baghdad Road Health Center for Health Care	45
1	4526	75.43	10417200	86.81	17.86 %	76560	Kirkuk Governorate/Civil Status Department	46
1	7614	127	17523600	146	89.80 %	127560	Kirkuk Governorate/Kirkuk Martyrs District	47
2	10865	181	25007280	208.39	32.00 %	203320	Ministry of Water Resources/General Authority for Survey	48
4	22278	371.3	51279600	427.33	28.66 %	301160	Diyala Governorate Office	49
1	1816.2	30.27	4180800	34.8	38.95 %	30280	Contracts Department, Karbala Governorate	50
1	3692.4	61.54	8498400	70.82	39.59 %	63160	Karbala Municipalities Directorate	51
1	3745.8	62.43	8620800	71.84	33.98 %	49160	Health Center in Karbala	52

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							(al-mulahak)	
1	13620	227	31306800	260.89	100.00 %	55080	Karbala schools schools 6	53
6	3850.8	64.18	8863200	73.86	100.00 %	286400	Karbala Central Library	54
3	53652	894	123480000	1029	70.30 %	1013280	Ministry of Water Resources/Head quarters	55
5	37320	622	85932000	716.1	49.90 %	554560	Karkh -Al University of Science	56
7	21420	357	49298400	410.82	72.17 %	420520	Ministry of Commerce/General Company for Foodstuff Trade	57
3	4488	74.8	10333200	86.11	21.50 %	89880	Ministry of Defense/Army Sports Club	58
2	41280	688	95076000	792.3	25.30 %	651200	Wasit / University College of Engineering	59
1	10524	175.4	24228000	201.9	28.00 %	187200	Mustansiriya -Al University/College of Education	60
2	40104	668.4	92325600	769.38	62.40 %	710800	Maysan Governorate Office	61
1	2226	37.1	5124000	42.7	51.60 %	32160	Cultural Center Maysan /	62
1	10020	167	23064000	192.2	31.20 %	161760	Complex of formations of the Ministry of Construction, Housing and Municipalities/ Maysan	63
1	2256	37.6	5193600	43.28	74.40 %	32560	Mayor of Amara District	64
1	2649	44.15	6097200	50.81	36.00 %	50960	Water Maysan Directorate	65

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1	4331	72.18	9967200	83.06	22.15 %	85160	Maysan Sewerage Directorate	66
1	1755	29.2	5041920	42.016	45.67 %	26720	Mayor ofal-mujar al-kabir	67
1	3930	65.5	9049680	75.414	100.00 %	69360	Mayor of Maimouna District	68
1	6180	103	14160000	118.8	99.00 %	62960	Guest House Building / Maysan	69
7	3540	59	8169600	68.08	80.00 %	359760	Jaber Ibn Hayyan School / Maysan	70
1	20220	337	46488000	387.4	55.34 %	62160	Department of Pharmacy and Medical Supplies/Maysan	71
1	3522	58.7	8112000	67.6	84.50 %	86200	Conference Palace / Maysan	72
2	213420	3557	491160000	4093	10.15 %	3825000	Civil Aviation Authority/Baghdad International Airport	73
1	9612	160.2	22128000	184.4	26.70 %	166360	Ministry of Defence/Information Systems Directorate	74
1	3094	51.57	71122000	59.35	84.80 %	45960	Cabinet/General Authority to Monitor the Allocation of Federal Imports	75
2	3054	509	70332000	586.1	32.47 %	556500	Office of the Prime Minister	76
2	9378	156.3	21588000	179.9	30.00 %	159400	Ministry of Water Resources/General Authority for Irrigation Projects	77

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3	3180	53	7330800	61.09	49.60 %	224480	General Authority for Ground Water/Wells Maintenance Department	78
1	42960	716	9922800	826.9	16.80 %	60440	National Intelligence Service	79
3	9796	163.26	22544400	187.87	30.50 %	749000	General Company for Transporting Passengers and Delegations	80
3	12150	202.5	27962400	233	23.80 %	179580	Ministry of Environment project	81
1	15600	260	35904000	299.2	37.40 %	235100	site No. 1) of the Iraqi National Intelligence Service	82
1	6324	105.4	14556000	121.3	36.80 %	100400	Chemistry laboratories at the College of -Al -Science Mustansiriya University	83
1	45060	751	103800000	865	100.00 %	1086000	Iraqi Airways General Company building	84
10	144394	2407	332322000	2769.3	6.00%	2441640	Buildings of the Iraqi Media Network	85
1	2274	73.9	5238000	43.65	58.20 %	56000	General Authority for Ground Water / Machinery and Equipment Maintenance Department	86

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1	4476	74.6	10300000	85.9	35.70 %	91600	of Directorate Environmental Protection in the Northern Kirkuk\Region	87
1	2844	47.4	6553200	54.6	74.00 %	48720	Building of the Directorate of Political Kirku\Prisonersk	88
1	10606	176.78	24412440	203.437	63.50 %	144000	Computers Class Directorate Building	89
2	5370	89.5	12360000	103	100.00 %	14400	Project for using solar heaters	90
1	16170	269.5	37218360	310.153	71.00 %	271500	Ministry of Agriculture building	91
1	6420	107	14800560	123.338	4.50%	85560	Baghdad Governorate Office Building	92
1	6660	111	15356400	127.97	63.00 %	102480	Building of the Department of Treatment and Destruction of Hazardous Chemical, Biological and Military Waste	93
1	27978	466.3	64403000	536.694	59.60 %	393200	The headquarters building of the Independent High Electoral Commission	94
1	8040	134	18578160	154.818	32.00 %	93940	Financial and Accounting Training Center Building	95
2	13200	220	30428520	253,571	33.80 %	169600	Department of Engineering -Reconstruction Ministry of	96

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							Construction, Housing, Municipalities and Public Works	
3	7560	126	17484840	145,707	23.90 %	89560	College of Dentistry Iraqi -Building University	97
1	2706	45.1	6240000	52	21.2%	55600	Ministry of Environment/Department of Protection and Environment of the Southern Basra -Region	98
1	9900	165	22731960	189.433	29.00 %	187810	Iraqi Housing -Fund Building Ministry of Construction, Housing, Municipalities and Public Works	99
3	15246	254.1	35000000	292.41	50.40 %	259050	The Office of the Presidency of the Republic building	100
2	58405	973.4	134420000	1120.17	20.00 %	906600	Government Palace building	101
1	2472	41.2	5693000	47.44	65.00 %	111760	Al bograd Health Center Building / Muthanna Health Department	102
4	24540	409	56568360	471.403	57.98 %	336480	Industrial Research and Development Department - Building Ministry of Science and Technology	103

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1	2880	48	6624000	55.2	29.20 %	82080	Building Research -Department Ministry of Construction and Housing	104
6	81666	1361	188000000	1566	26.00 %	1430940	Building of the General Secretariat of the Council of Ministers	105
1	64320	1072	280253000	2170.1	24.00 %	1530000	Arar border crossing	106
3	35599	593	81930000	682.75	16.20 %	526300	The buildings of the Iraqi parliament	107
290	671040	11184	1544424000	12870	100.00 %	11136000	grade model -12 school (number (of 290 schools	108
25	66480	1108	153150000	1275	24.00 %	1200000	Model health centers (No. 25)	109
546	3124192.2	83830.99	7464230060	62353.052	5432.86%	57752324		the total

Most of these buildings were built in the last four decades. However, the availability to install solar panel was assessed. All the mentioned buildings have enough space especially at the roof which make the using of solar energy possible. Investing in solar energy infrastructure can stimulate economic growth in Iraq. The construction and maintenance of solar energy, as well as the manufacturing of solar panels and components, can create jobs and boost the local economy. Furthermore, solar energy reduces the need for costly fuel imports, contributing to long-term economic stability. Evern though, solar panels do not have the ability to store energy, meaning that they can only generate electricity when the sun is shining when off- grid is used, however, the mentioned system still beneficial especially in Iraq which has long sunshine duration time. By converting these buildings to utilize solar energy, an average annual output of 62,353 kilowatt-hours can be provided. Knowing the fact that each unit of electricity generated in Iraq can emit around 869g of CO2 (IEA), thus the significant amount of clean electricity generation would lead to an annual emission reduction of approximately 167,662 tons of carbon emissions. The price of each tone of carbon is approximately 60 USD. Thus, around 10,059,720 USD can be provided annually.

5. CONCLUSION

As countries worldwide strive towards achieving sustainable development goals and combating climate change effects effectively, Iraq stands at a crucial juncture. By promoting solar energy

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projects and harnessing the abundant sunshine, Iraq can contribute significantly to reducing carbon emissions and mitigating climate change impacts. The results of this study emphasize the potential for solar power to provide alternative sources of electricity while positively impacting the environment, economy, and overall well-being of Iraq's population. It is imperative for government institutions, businesses, and communities to embrace this renewable energy revolution and work towards a greener future together. In addition to the benefits of solar energy, Iraq must also focus on diversifying its renewable energy portfolio to include wind, hydro, and biomass. These efforts would enhance energy security and reduce dependency on fossil fuels. The integration of energy efficiency measures and the modernization of Iraq's electricity grid are essential to maximize the benefits of renewable energy projects. Moreover, fostering international partnerships and attracting foreign investments can accelerate the transition to a low-carbon economy. Public awareness campaigns and educational initiatives are vital to ensuring community involvement and support for these green initiatives. By aligning its energy strategy with global trends, Iraq can set an example in the region for sustainable development and climate resilience.

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