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Solar Energy Sustainability in Jordan

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Abstract

Jordan is a country with highly fossil fuel deficiency and thus other energy sources are needed to be explored. Solar energy in Jordan is highly recognized as a good source of energy and an excellent substitute to the fossil fuel. The solar energy in this article is obtained via data bases and modeling techniques for the specified place coordinate and angle of inclination. The angles of sun irradiations are different throughout the year; therefore solar energy needs to be magnified by optimizing the angle of inclination of solar cells. In this research, the optimized angles throughout the year are obtained to be in the range: 10˚ - 60˚. Solar energy can serve the residential building, the findings of this research show that every 1 m² of the solar cell may contribute to about 60% - 70% of customer needs of electricity throughout the year. The application of solar energy concept in the design of building will play an important role in energy sustainability.

Keywords

Solar Energy, Inclination Angle, Sustainable Buildings

1. Introduction

During the last two decades, the increasing energy demand has brought challenges to Jordan due to country's limited resources. Hence, solar energy applications have more attention to substitute the depletion of the fossil fuel that causes dramatic pollution to the environment. Jordan has established a strategic change and reform of its national economy and energy strategy [1]. Jordan has assisted programs utilizing solar energy. Assessment involved systematic monitoring of implementation of appropriate technologies, demonstrations, and pilot projects [2] [3].

Due to high and reliable solar irradiance in Jordan (5.5 $kWh/m^2 \cdot d$), the usage for solar energy in Jordan has

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high potential for about 330 sunny days per year using solar panels [4]. Solar radiation also differs according to seasons, in winter the sun becomes lower in the sky and higher in summer because sun ray's angle changes due to the earth's tilt angle [5].

The distribution of total radiation on a horizontal surface over a day was examined by Liu and Jordan who showed that the ratio of hourly to daily radiation could be correlated with the local day length and angle which differs through the year [6]. Solar energy encounters many parameters that affect its cultivation during the year such as sunshine duration, relative humidity, temperature, and cloudiness. The solar panels inclination therefore should be dynamically changed during the seasons at certain place [7].

However solar radiation differs along the seasons. The results of Liu and Jordan were confirmed by Collares Pereira and Rabl [6] using a wider database for the average distribution of solar radiation associated with different coordinates of time and place. Saraf and Hamad [8] found the yearly optimum tilt angle in Basra, Iraq was higher than the latitude by about 8˚. Gopinathan [9] showed the optimum tilt angle of oriented sloping plates is almost equal to place latitude.

Both Gopinathan [10] and Soulayman [11] showed the optimum tilt angle of oriented sloping plates is almost equal to place latitude.

However, researchers have different approaches for optimal angles for solar collectors in different places, because the radiation pattern changes from location to location and time to time [12] [13]. Thus, the aim of this research is to optimize the angle of inclination for Jordan during the year.

2. Methodology

The angles of sun irradiations are different throughout the year. Therefore, the solar panels should be dynamically inclined with different angles. This article spots the light on solar energy utilization depending on solar energy databases and modeling techniques. The information about solar energy, temperature, and electricity consumption was collected from several organizations namely: National Center for Research and Development, Ministry of Energy and Mineral Resources, and Jordan Meteorological Department. The sunshine hours in Jordan zone were taken from the time and date calendar. Solar Energy Modeling was performed using Meteonorm software Version 6 for modeling solar energy with inclination angle of panels for Jordan database.

3. Solar Energy for Buildings in Jordan

The major goal of this research is to explore that the collected solar energy can offset the electrical energy consumption in residential buildings (**Table 1**) [14]. The aim of the research can be achieved via many tracts. The first tract is to optimize solar panel angle of inclination throughout the year. The second tract is to design sufficient area in the residential buildings for panels to be installed. The third tract is to manage the energy in the building in the basis of building design and geometry, and daily wise management of energy.

Fossil fuel depletes and costly increases with the time, furthermore it causes environmental problems such as global warming. Therefore, solar cells must be oriented and distributed effectively depending on time in the year and depending on the building size. The savings of electricity can be enhanced by altering the daily time of wakeup and sleep. The daylight hours may help in utilizing the natural sunlight instead of electricity [15]. The implementation of Daylight Saving Time (DST) creates an additional hour of higher outdoor air temperature and solar radiation during the primary cooling times of the evening [16]. California Energy Commission [17] [18] conducted a simulation-based study to examine the effects of DST on statewide electricity consumption. Consequently, by concise management, collecting sun irradiation and fitting the daily man activities to sunshine will compensate large part of electricity for residential building.

The records about the solar energy in Jordan spots the light on the truth that Jordan is rich in sun irradiations as **Table 2** shows the data about sunshine hours and solar energy in different places in Jordan in the year [19]. The average of the data values shows the relative trend between solar energy and sunshine period as it is shown in **Figure 1**. The solar energy data accumulates an estimated average energy value on the yearly basis of about 2056 kWh/m^2 for Jordan.

In **Figure 1**, the information obtained about the solar energy can be represented via analytical model that incorporates the sunshine period as a major parameter. After calibration, this model can forecast the energy for specific place coordination and variable angle of inclination.

Table 1. The annual electricity consumption per capita in residential building in Jordan.

Equipment	Service (hours/day)		Operation	Consumption	Percent of Consumption
	Summer	Winter	(hours/year)	(kWh)	
Lighting	7	6	2340	514.8	21.28%
Refrigerator	16	8	4392	933.3	38.58%
TV	12	7	3372	288.3	11.92%
W. Machine	2	2	220	89.1	3.68%
Iron	1	1	130	117	4.83%
Fan	14	0	420	23.5	0.97%
Water Pump	1.5	1.5	135	10.8	0.45%
Freezer	10	2	2160	113.4	4.69%
Water Cooler	2	0	90	0.9	0.04%
Vacuum Cleaner	1	1	120	24	0.99%
Washing Dryer	0.5	0.5	180	5.4	0.22%
Hear Dryer	0.5	0.5	50	7.5	0.31%
Heater	1	1	60	2.7	0.11%
Geyser	1	5	480	192	7.94%
Air Condition	10	0	350	96.3	3.98%
			Total	**2419**	**100%**

4. Solar Energy Modeling throughout the Year

In this section, the solar energy in Jordan is being modeled for different angle of solar panel inclination. Meteonorm version 6 uses data bases about the specified place coordination and gives the estimated solar energy for different panel inclinations. It comprises physical and environmental parameters applicable for certain coordinate. The estimation of solar energy is being adjusted for different angle of orientation of solar panel due to sun movement during the months of the year. The modeling process is shown on **Table 3** that depicts the solar energy throughout the months in the year for different solar cell inclination.

The energy values in **Table 3** can be optimized to maximum solar energy for each month, for example for January the maximum energy is obtained when the panel is inclined to 60˚. **Figure 2** shows the optimum solar energy with optimum solar cell inclination in each month in Jordan.

In this research, the focus is to optimize solar energy cultivation along the year. Hence, the angle of inclination is given the great attention. The data recorded about solar energy is given via panels of fixed inclination (**Table 2**). **Figure 3** compares between the energy recorded data for fixed panels and the dynamic estimated energy values for variable angle of inclination during the year.

The variable angle of inclination represents other important parameter of modeling in addition to the sunshine period. As the sun moves in orbital track, the sunshine period and the sun irradiations direction are variable along the year, which creates the seasons. In Jordan, the year is classified into four seasons: Summer, fall, winter, and spring. The summer season extends from May until August. The fall is characterized to be in September and October. Winter extends from November until February, and spring denotes to March and April. **Figure 4** represents each season and the solar energy accumulated with it within variable angle of inclination. For example, the figure shows that the solar energy gained in summer is as high as 1002 kWh/m^2.

As per for **Figure 4**, the optimized energy upon yearly basis is computed to be 2501 kWh/m^2 and this is also illustrated in **Table 4**. This value overcomes the value of general solar fixed cells (2056 kWh/m^2) that seen in **Figure 1**. By comparing the total energy value (2501 kWh/m^2—**Table 4**) and the value of electricity consumption

Table 2. Data of sun shine period (hours) and energy (kWh/m^2) during the report in 2007 in different stations in Jordan.

Sunshine	Amman	Irbid	Dhlail	Azraq
JAN	5.1	5.5	5.5	6
FEB	5.8	5.2	6.5	6.6
MAR	7.7	7.5	8.6	8.4
APR	9.4	9	9.7	9.3
MAY	9.8	9.6	9.9	9.6
JUN	11.8	11.3	11.7	11.1
JUL	12	11.8	12	11.2
AUG	11.7	12.2	11.6	11.1
SEPT	10	10	11	9.7
OCT	8.8	8.5	9	8.7
NOV	6.2	6.3	6.7	7
DEC	5	4.2	5.7	5.5
Energy	**Amman**	**Irbid**	**Dhlail**	**Azraq**
JAN	3.2	3.1	3.2	3.3
FEB	4.1	3.7	4.1	4.2
MAR	5.4	5.1	5.5	5.7
APR	6.8	6.4	6.8	6.8
MAY	7.1	6.9	7.5	7.5
JUN	8.3	7.7	8.4	8.4
JUL	8.1	7.6	8.3	8.1
AUG	7.4	7.5	7.7	7.3
SEPT	6	6	6.5	6.2
OCT	4.5	4.6	4.9	4.9
NOV	3.3	3.3	3.3	3.7
DEC	2.9	2.9	2.9	2.9

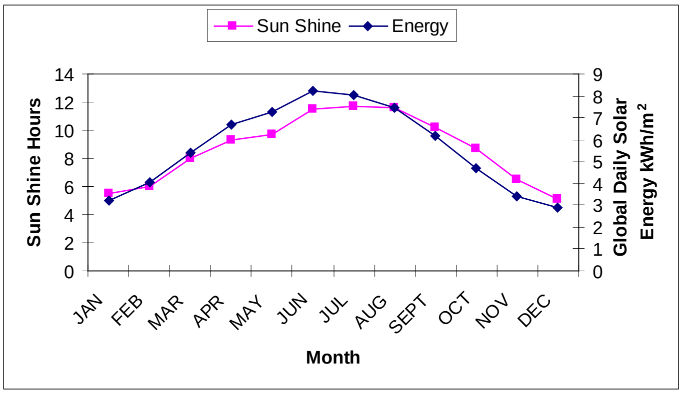

Figure 1. Average sunshine hours and global daily solar energy recorded in Jordan.

Table 3. The estimated solar energy kWh/m^2 during months of the year for different solar cell inclination.

	Solar Energy kWh/m^2					
	10˚	**20˚**	**30˚**	**40˚**	**50˚**	**60˚**
JAN	119	136	149	158	163	164
FEB	123	135	143	148	149	147
MAR	175	184	189	189	185	176
APR	204	207	205	198	186	170
MAY	241	236	225	209	189	163
JUN	254	244	228	207	182	153
JUL	262	253	239	219	194	164
AUG	245	245	238	226	208	185
SEP	216	226	229	227	218	204
OCT	185	203	215	221	222	216
NOV	136	154	169	178	183	183
DEC	111	127	140	149	155	156

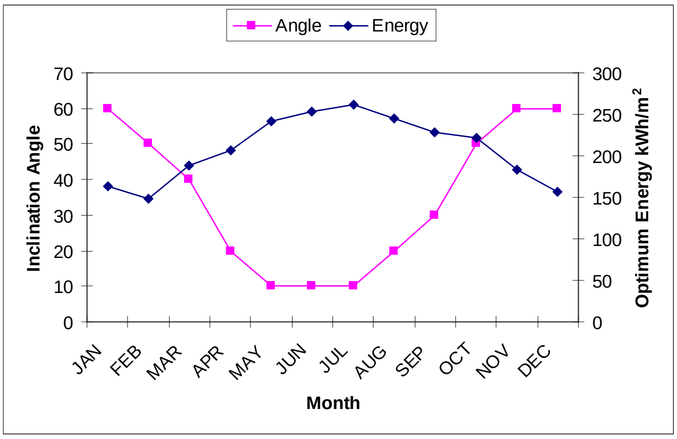

Figure 2. Optimum solar energy with optimum solar cell inclination in each month in Jordan.

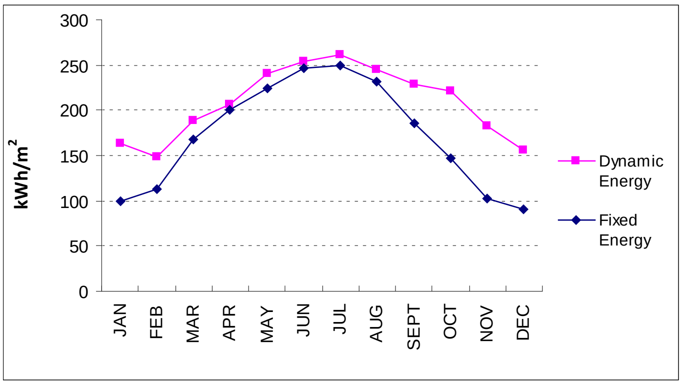

Figure 3. The comparison between energy gathered by panels of dynamic angle of inclination and panels of fixed angle of inclination.

Table 4. The optimal solar energy cultivated during months in Jordan.

MONTH	Inclination Angle	Optimal Solar Energy (kWh/m^2)
JAN	60	164
FEB	50	149
MAR	40	189
APR	20	207
MAY	10	241
JUN	10	254
JUL	10	262
AUG	20	245
SEP	30	229
OCT	50	222
NOV	60	183
DEC	60	156
Total Energy		**2501**

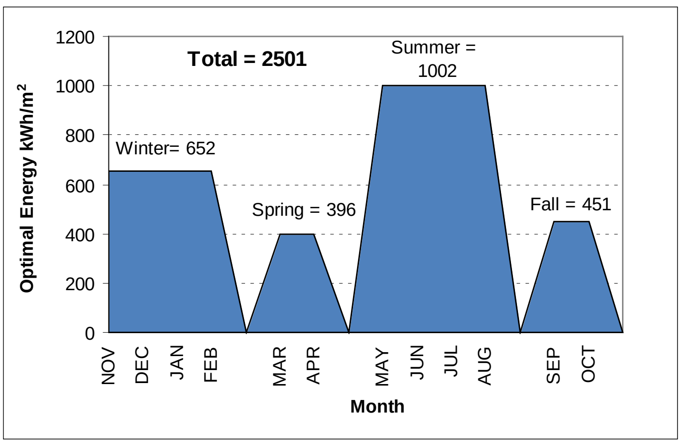

Figure 4. The optimal solar energy cultivated in each season in Jordan.

for residential building per year for single customer (2419 kWh/capita—Table 1); it is worthy to take in consideration that if the solar energy is efficiently converted to electricity then every 1 m^2 of the solar cell will contribute to about 60% - 70% of customer needs of energy in the year. Consequently, the area occupied by solar panels is another important parameter in energy estimation. Hence, the idea of utilizing solar energy in buildings is an important scenario for sustainability.

5. Conclusions

Jordan is a place that it is recognized of plentiful high solar radiation. The solar energy depends on the sun travel along the years, and thus the sunshine period and sun irradiations direction are variable during the year. Solar energy cultivation is optimized considering dynamic variation of the angle of solar cell inclination through the year.

In this research, it’s shown that solar energy can serve the residential building consumption of electricity as every 1 m^2 of the solar cell may contribute to about 60% - 70% of customer needs of energy in the year. In addition, combining solar energy concept in the design of building will lower the cost of energy use and will play an important role in sustainable development of buildings.

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