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Feasibility Study of Renewable Energy Technology Integration in Housing Sector: A Real Application in Saudi Arabia

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ABSTRACT

The rapid growth of renewable energy globally is connected to the developed performance of the system especially in solar and wind powers. This is in association with enormous research conducted worldwide. After Saudi Arabia has acknowledged the new vision of the country in 2030 which of the major aims is to enhance the utilisation of renewable energy technology. The government has supported various research in sustainable power. Since then, many work has been published with regard to the mentioned subject. This research focus on real application of utilising renewable energy at a given house consist of five people based on their energy use. It was found that wind power and PV system have attributed with 37.5% and 41.0%, respectively. The research will highlight that the utilisation of these systems are quite promising and can lead to massive energy saving in demotic building.

Keywords: Renewable energy, PV system, wind turbine, thermal storage, Saudi housing sector

INTRODUCTION

It has been known universally that renewable energy is a new term that could describe a power which derived from a sustainable and continues source such as PV, solar thermal and wind power. However, it seems that this is not the always the case. Human have used renewable energy in quite early ages. But, it has been developed significantly. The main benefit of this resource is that it helps to decrease the reliance on fossil fuel which is not only a source that will disappear one day, but also it has a negative impact on our planet. In addition, it is quite important to mention that the main supply for this resource is derived from the massive power of sun's radiation.

Renewable energy technologies have gained admitted a major awareness in order to achieve the desired environmental usable power. Wind and solar are among the most attractive alternatives Hongxing [1], Diaf [2], Nfah [3], Taleb [4] and Ramli [5]. These power are effected by outdoor conditions such as amount of solar radiation, wind speed and etc. [6]. The renewable energy technology has a rapid globally increase, thus, storing such energy still a major barrier Zhou [7]. Renewable energy technology is wildly investigated and developed. For instance, Kalinci [8], Dursun [9] and Mason [10] in Turkey, and Silva [11] in Brazil. The later evaluated the use of a photovoltaic-fuel cell-battery system.

As far as the potential of renewable energy technology in Saudi Arabia is concerned, average range of availability of solar radiation vary from 4 to 7.5kWh/m² while it is only 1 7.5kWh/m² across Europe El Khashab [12]. This indicates how the chance of exploitation of renewable energy is promising in the region. Similarly, Al-sharafi [13] in a work done to investigate solar and wind energy production in Saudi Arabia and a selection of cities globally. The work suggested that the exploitation of Renewable energy in Saudi Arabia is better than in Toronto (Canada) and Sydney (Australia).

Due to the rapid increase in population in Saudi Arabia, dwelling is considered by far the most sector of energy consumption in the country which dominate 40-50% of total energy usage in the kingdom Shaahid [14] and Alrashed [15]. Due to many reasons such as the new vision of 2030 in Saudi Arabia which aims to move away from fossil fuels reliance, the number of research has sharply rise in Saudi Arabia Rehman [16], Mokheimer [17], Elhadidy

[18], Rehman [19] and Shaahid [20]. For example, King Abdulla city for Atomic and Renewable Energy (KA-CARE) has introduced and lunched a new solar Atlas in 2014. The site provides accurate data available online for number of locations spread over the kingdom. This aid researcher to carry out high quality of research related to renewable energy technology Sulaiman [21]. A study done by Nidal [22] who has designed a power tower in the University of King Abdul-Aziz in the city of Jeddah. The thermal power transferred to the water in the heat ex-changer which is heated by the molten salt was about 11.26kW. Moreover, another investigation of wind energy was carried out by Baseer [23] in the city of Jubail in different locations. The wind speed varies from 1.8 to 3.3 MW. The best location was found in Eastern part of the industrial area of the city.

Although solar radiation in Saudi Arabia seems quite promising, there is a clear variation across the country. Abd-ur-Rehman [24] conducted a research for the optimum selection of solar water heating systems based on their com-parative technology for demotic. The research observes that Nejran and Bisha cities perform higher values of solar radiation compared to the city of Jeddah. As a result, utilisation of solar power generally in these regions will in-crease the output especially in effortless systems such as solar water heating. Although many investigations indicate the opportunity of wind and power power in the region, there is more emphasis on the efficiency of the later since there is a clear evidence of the availability of solar radiation in Saudi Arabia compared to the entire world Alrashed [15].

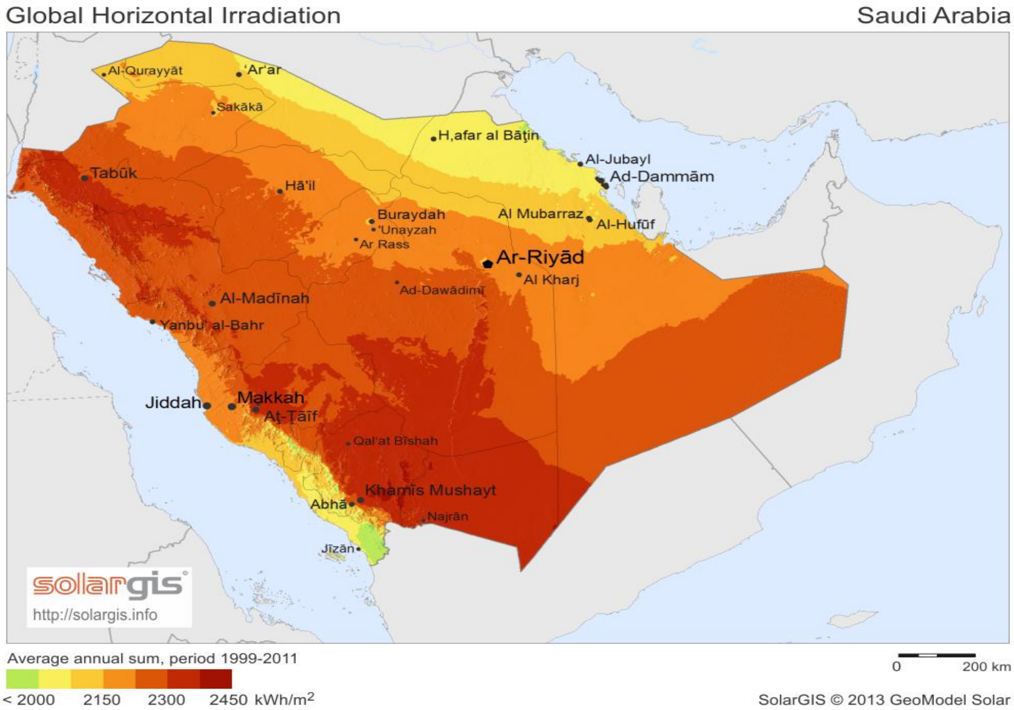

Fig. 1 Amount of solar radiation across Saudi Arabia. Source: Renewable Resource Atlas, King Abdullah City for Atomic and Renewable Energy (KA CARE), Saudi Arabia, ⟨https://rratlas.kacare.gov.sa⟩, 2015

Location and Local Climate Condition

The location of the project is in the capital city of Saudi Arabia which called Riyadh with 24.4 Latitude, and 45 lon-gitudes. It sits in the centre of Arabian Gulf countries. The climate is extreme in both summer and winter. According to World travels the temperature could reach 45 degrees easily during summer period. However, surprisingly it full significantly in winter time, specially, at night. The city is quite rich in terms of sunny days during the course of the year which make it easier for PV and solar thermal systems to make use of this gift.

Location Information and Best angle for PV Array

As it already given in the last section, the city located in the middle of Saudi Arabia with 24.4 Latitude, and 45 lon-gitudes (see Fig. 1). According to PV system, the best tilted angle is 20° south, obviously, toward the bath of the disk if the sun. In order to calculate the load for the entire year, two days have been selected only. One to represent winter condition and the other one to represent summer one. In addition, both of them will be applied for six months to come up with the load for the whole year. So, the 20th December is the selective say for winter condition which equal the day 365 in the year account. By looking at tables appear in Fig. 2 and 3, it can be seen the amount of solar radiation in the case of both summer and winter which can be calculated by the following formula:

Amount of solar radiation $$(H_{T}) = H_b * R_b + H_d((1+\cos\beta)/2) + H * \rho g((1-\cos\beta)/2)$$

It also can be noted that there is no considerable different between total solar radiation in summer and winter due to the fact that the day time length is to quite differ from summer to winter as well as the local condition with clear sky mostly. As far as energy load is concerned, the total energy load has been calculated for each summer and winter period. Energy load for summer is (8603.0 Wh) whereas for winter is (5735.0 Wh), and when this Figures changed to Kwh it becomes as following:

- Energy load for summer = 1574.34 kwh
- Energy load for winter = 1043.77 kwh

So, in total there is 2618.11 KWh energy load when the course of the year divided into period 183 days for summer and 182 for winter.

The aim of this paper is to meet 75% of a house consists of five people by energy resource. Furthermore, 100% of hot water energy load should come from solar thermal. In terms of the PV output, it has to achieve at least 50% out of the 75%, and the rest could be generated by wind turbine. In order to satisfy with the aim, the following objectives have to be met:

- Determine the wind turbine rotor diameter that would enable the family to provide the percentage required of electricity.
- Determine the PV array area to meet at least 50% of the electricity need for the family.
- Determine the solar collector area to meet the whole need of the family of hot water.
- Determine the size of the tank

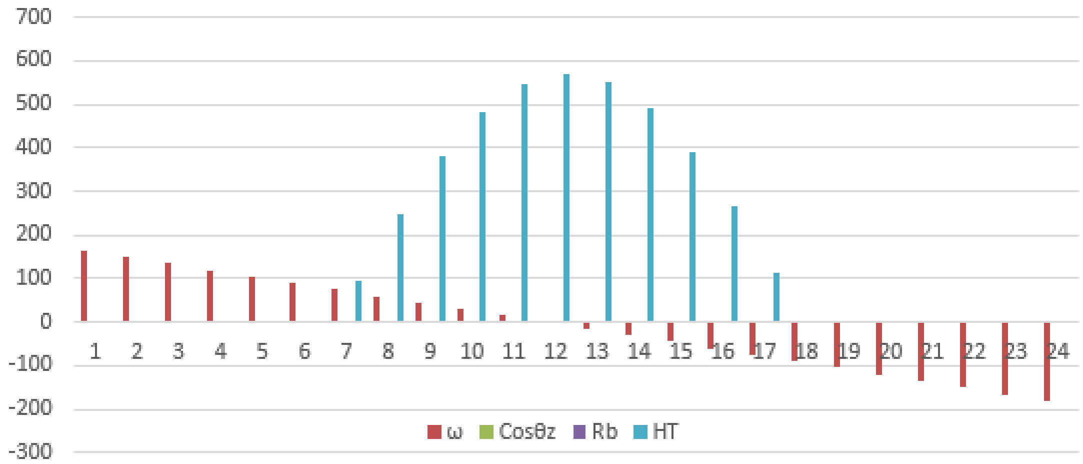

Fig. 2 Winter solar radiation performance for the case of winter and summer

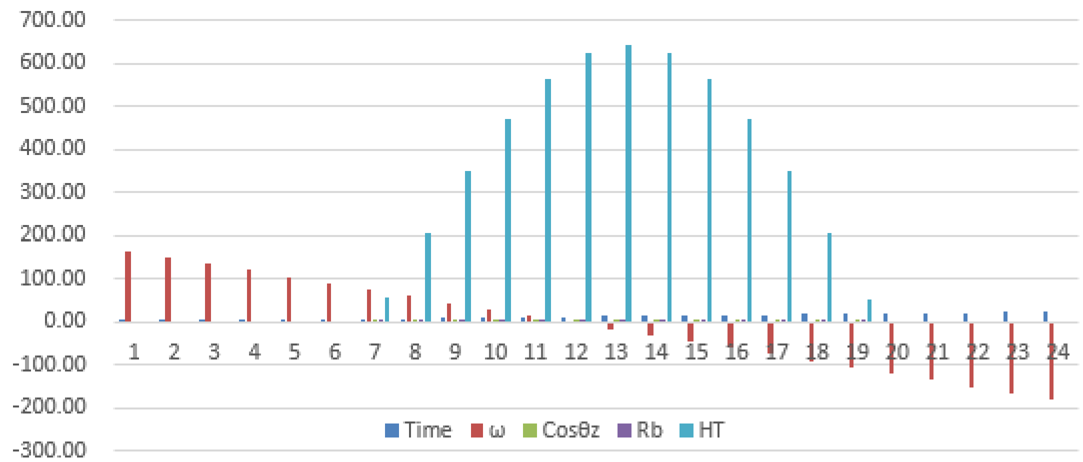

Fig. 3 summer solar radiation performance for the case of winter and summer

WIND TURBINE

Bins Method

Bins method could be used to protect the wind speed in a particular site by gathering air velocity and the number of each one for specific time. The main benefit of this technique is to save time mainly.

Wind Turbine Calculations

As it has been motioned earlier that wind power is require providing 50% or less of electricity need. In addition, in order to determine that there is some important Figures which have to be calculated. The first one is Wind speed for the whole year. The second one is wind speed duration whereas the following point is coefficient of performance which can be calculated by the following formula: $C_p=0.055U-0.0032U^2$ where: Cp is the coefficient performance and U is the wind velocity. Next point is power, which can be calculated by the following formula: power = (1/2 * d * ρAU^3**)** where: ρ is the coefficient performance, A is the rotor area and U is the wind speed.

The Area of Wind Turbine and Diameter

Knowing the total energy that produced from the system which is 461.39 kWh, then the area can be calculated by the following formula {2618.1(kWh) * 0.75 * 0.50 = A * 461.3 (kwh/m^2)} so, A = (**2.12m^2**)**.** In terms of diameter, since the area has been determined, the diameter of the turbine would be easy to calculate from the following formula: Diameter (D) = (2.12 m^2*4/3.14)$^{1/2}$. ***So***, Diameter = 1.65m

Table -1 Table of Wind Method Calculation

Wind speed [m/s]	Hours [Hrs]	COP	Power [W/m^2]	Energy [Wh/m^2]
1.5	893	0.08	0.2	140
2.5	875	0.12	1.1	988
3.5	1006	0.15	4.0	4066
4.5	1065	0.18	10.2	10904
5.5	1030	0.21	21.0	21679
6.5	806	0.22	37.5	30261
7.5	720	0.23	60.3	43432
8.5	621	0.24	89.2	55423
9.5	539	0.23	123.2	66419
10.5	417	0.22	160.0	66709
11.5	291	0.21	195.8	56968
12.5	212	0.19	225.2	47747
13.5	117	0.16	241.0	28202
14.5	93	0.12	233.8	21743
15.5	35	0.08	191.7	6709
	8720	0.18	1594.4	**461391**

PV SYSTEM

Types of PV Cells Used

It has to be mentioned that there are several types of PV cells such as Monocrystalline, Polyceystalline and Ambrophous. Moreover, they are varied from one time to another in terms of performance and efficiency. However, (monocrystalline silicon) which is considered as the best type as Boyle (2004) has pointed out. Furthermore, this type of PV will be used in the project which has 45 NOCT and 0.40 βp.

Calculation Consideration

As it has been highlighted before, PV output should meet at least 50% of the 75% of the house electricity load. The first thing that has to be known is the area of the PV array which needs the following to be determined:

- Outdoor temperature (ambient), for both summer and winter.
- Solar radiation for both summer and winter
- PV efficiency for both summer and winter which can be calculated by the following:
  PV efficiency = η (1-βp(Tc-Tr))
  where: η is the PV efficiency and βp is the temperature module coefficient and TC is the temperature of the cell.
- PV Output which can be determined by the following formula: $A = Q_{load}/ Q_{pv}$
- Total PV output

PV Area

In terms of the area of the PV, it can be determined by the following formula:
[A * (Qu) = 75% * 50% * Q load]. However, since there are two different periods (summer and winter) there has to be a consideration of the these differences so, the equation will be: A * Qu (for winter) * 183 (number of winter days + Qu (for summer) * 182 (number so summer days) = 0.75% * 0.50% * (Q load for winter * 183) + (Q load for summer * 182)
= (5.10) **m^2**
Since there is two different load and two different conditions for summer and winter, the output for each one will vary as it can be seen in Fig. 4. There is only 33% meeting energy if the system was in summer condition whereas 42% in winter condition.

Table -1 Winter Calculation of PV

Solar Time	Solar Radiation	Electrical Energy Load (W)	Ambient Temp.(W)	PV Cell Temp.	PV EFF.	PV Output	PV output (total)	balance
	wh/m2	Wh	°C	°C	%	wh/m2	wh	wh
1	0	195	12.50	12.50	12.60	0	0	195
2	0	125	11.00	11.00	12.67	0	0	125
3	0	95	10.50	10.50	12.70	0	0	95
4	0	85	9.50	9.50	12.74	0	0	85
5	0	85	8.00	8.00	12.82	0	0	85
6	0	85	8.50	8.50	12.79	0	0	85
7	96	105	9.00	12.00	12.62	12.11	62	43
8	248	175	11.50	19.25	12.28	30.46	156	19
9	379	295	13.42	25.28	11.99	45.49	232	63
10	481	250	14.67	29.70	11.77	56.64	289	-39
11	546	230	15.86	32.92	11.62	63.43	324	-94
12	569	215	18.49	36.29	11.46	65.25	333	-118
13	550	220	19.23	36.43	11.45	63.03	322	-102
14	490	225	20.45	35.76	11.48	56.25	287	-62
15	392	210	27.00	39.25	11.32	44.35	227	-17
16	263	210	26.00	34.23	11.56	30.43	155	55
17	113	255	25.94	29.47	11.79	13.30	68	187
18	0	370	24.87	24.87	12.01	0	0	370
19	0	440	22.32	22.32	12.13	0	0	440
20	0	445	19.43	19.43	12.27	0	0	445
21	0	405	14.00	14.00	12.53	0	0	405
22	0	380	12.65	12.65	12.59	0	0	380
23	0	345	11.41	11.41	12.65	0	0	345
24	0	290	8.35	8.35	12.80	0	0	290
Total/Average	4128.18	5735.00	15.61		12.19	480.73	2456	3279

Table -3 Summer Calculation of PV

Solar Time	Solar Radiation wh/m^2	Electrical Energy Load (W) Wh	Ambient Temp.(S) °C	PV Cell Temp. °C	PV EFF. %	PV Output wh/m^2	PV output (total) wh	Balance wh
1	0	293	22.50	22.50	12.12	0	0	293
2	0	188	21.00	21.00	12.19	0	0	188
3	0	143	20.50	20.50	12.22	0	0	143
4	0	128	19.50	19.50	12.26	0	0	128
5	0	128	18.00	18.00	12.34	0	0	128
6	55.76	128	18.50	20.24	12.23	6.82	35	93
7	207.81	158	19.00	25.49	11.98	24.89	127	30
8	349.43	263	21.50	32.42	11.64	40.69	208	55
9	470.98	443	23.42	38.14	11.37	53.55	274	169
10	564.17	375	24.67	42.30	11.17	63.02	322	53
11	622.65	345	25.86	45.32	11.02	68.65	351	-6
12	642.43	323	28.49	48.57	10.87	69.82	357	-34
13	622.16	330	29.23	48.67	10.86	67.59	345	-15
14	563.23	338	40.45	58.05	10.41	58.65	300	38
15	469.66	315	37.00	51.68	10.72	50.34	257	58
16	347.81	315	36.00	46.87	10.95	38.09	195	120
17	206.00	383	35.94	42.38	11.17	23.00	118	265
18	53.88	555	34.87	36.55	11.45	6.17	32	523
19	0	660	32.32	32.32	11.65	0	0	660
20	0	668	29.43	29.43	11.79	0	0	668
21	0	608	24.00	24.00	12.05	0	0	608
22	0	570	22.65	22.65	12.11	0	0	570
23	0	518	21.41	21.41	12.17	0	0	518
24	0	435	18.35	18.35	12.32	0	0	435
Total/average	5175.96	8602.50	26.02		11.63	571.27	2919	5684

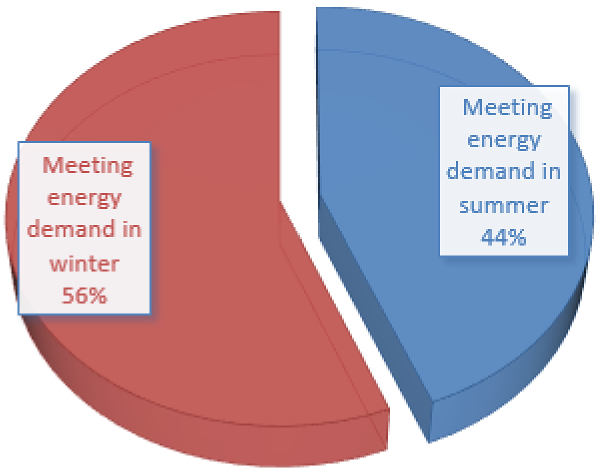

Fig. 4 Demand meeting percentage in winter and summer

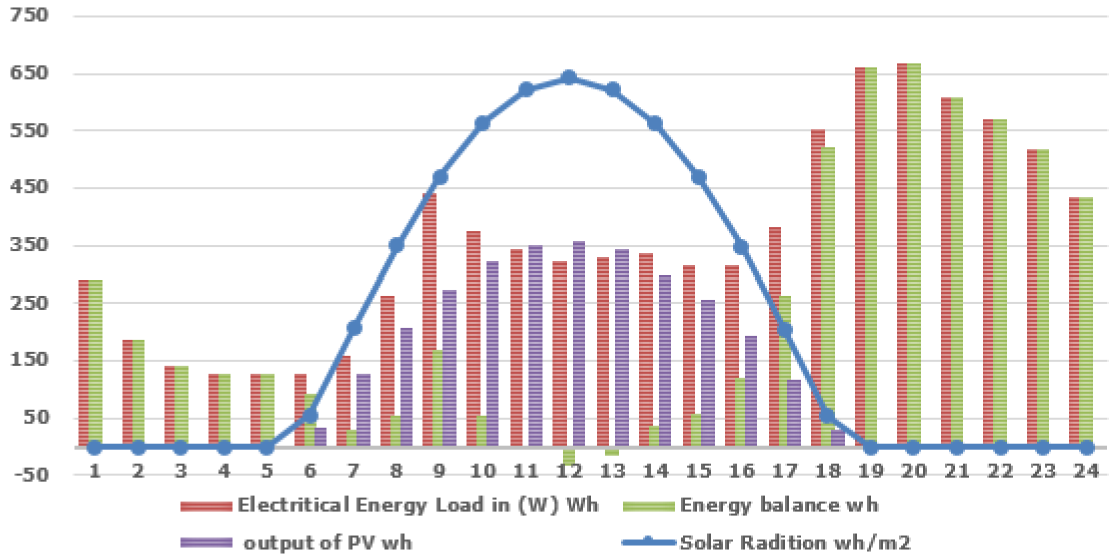

Fig. 5 PV summer performance

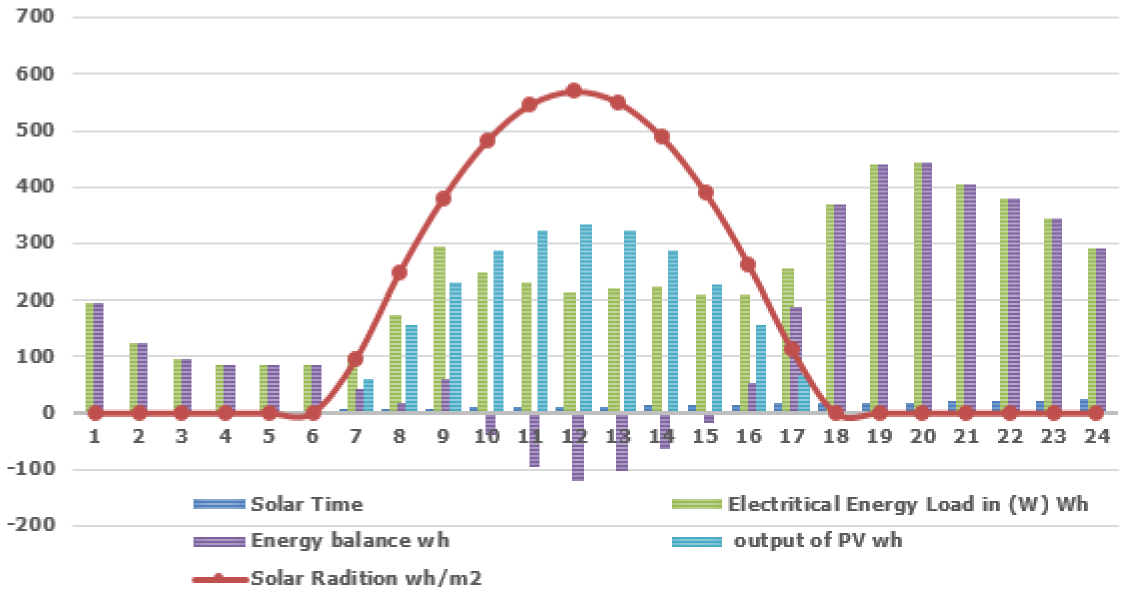

Fig. 6 PV winter performance

PV Performance and Discussions

By looking at the two different performance for PV in summer and winter it the following points could be considered, the first one is the amount of solar radiation, there is no a significant gap between the two different period as it was expected to be. For instance, the solar radiation in summer peaked at just over 600 w whereas in winter it peaked at just under the same Figure. However, the major different is the length of day time in each period. Similarly, PV output has no major different in terms of maximum protection at fixed time. However, the day time length is playing the major role here to determine the total output of PV.

PV Inverter

Since PV generates power with DC load, it has to be transferred to AC when using any equipment that requires such load. As a result, there could be some loss due to inverter process. Because of that there should be some modification for the area of the PV to adjust the shortage that occurs when using inverter. In this case the area of the PV could extend to be (6.3 m^2) instead of (5.10 m^2)

SOLAR THERMAL SYSTEM

Types of Solar Thermal System

There several types of water heating systems and each one have its own characteristics and performance. For instance, natural circulation system which called thermosyphon, open loop forced-circulation system and system with antifreeze and internal heat exchanger. Thermosyphon system is considered as the simplest system where there is no need for machines to circulate the water from the collector to the tank. However, the storage tank has to be located above the collector to provide natural ventilation. In terms of open loop system, it is more complicated where there is a need for different thermostat to control pump. The last system is antifreeze with heat exchanger, which is suitable to be used in cold climate, but the main problem in this system is that there is some heat loss due to heat exchangers. In the project case and condition, thermosyphon is the best choice as there is no freezing condition occurs except in a quite short time in winter's nights. One of the most important aspects that make this system quite attractive is that it does not require that much of machines maintenance. As a result, this would reduce operation costs significantly.

Amount of Water Requited for the Family

The total water requited for both summer and winter will be calculated separately as following:

Winter Hot Water Requited

In order to calculate the require hot water for winter there are some Fig. s that has to be considered For example, number of people, target hot water and average ambient temperature. So,

$$5 * 30 * 4.19 * 1000 * (60-15.6) / 10^6 = 46.5 \text{ MJ}$$

Summer Hot Water Requited

In the case of summer, the same variables that have to be considered first to determine the amount of hot water over summer.

$$5 * 30 * 4.19 * 1000 * (60-20.5) / 10^6 = 21. \text{ MJ}$$

Fig. 7 indicate graph of hot water use in both summer and winter. It can be seen that there is more amount of water used in winter than in summer, especially, in early morning.

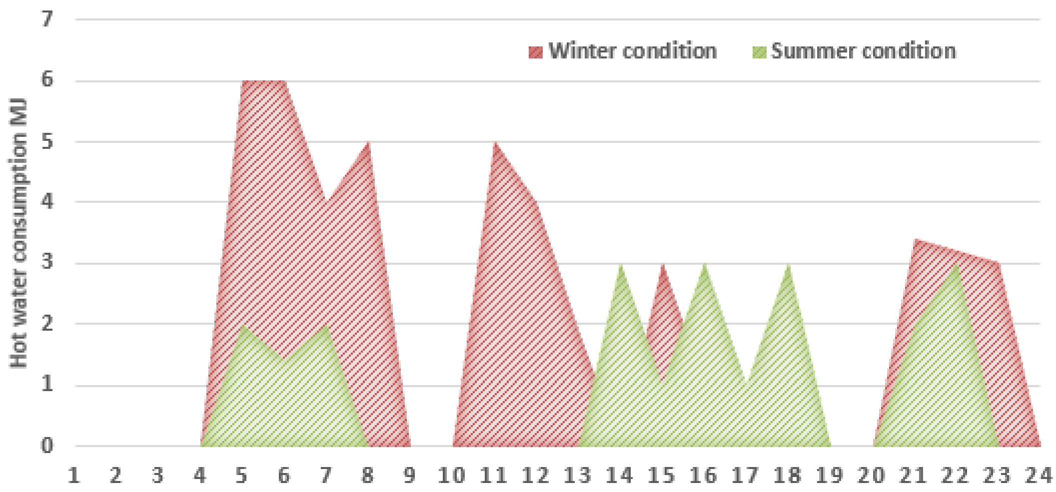

Fig. 7 Hot water consumption in summer and winter (MJ)

Table -2 Solar Thermal Calculation for Winter Condition

Solar Time	Solar Radiation wh/m2	Ambient Temp.(W) ℃	Building Load Wh	Q_{in} Wh/m2	Collector Loss Wh/m2	Tank Loss Wh	Qu Wh/m2	Qu total Wh	Tank-i ℃	Tank-f ℃
1	0	12.50	0	0	0	169.00	0	-169.0006	60.00	59.48
2	0	11.00	0	0	0	172.49	0	-172.4924	59.48	58.95
3	0	10.50	0	0	0	172.39	0	-172.3881	58.95	58.42
4	0	9.50	0	0	0	174.06	0	-174.064	58.42	57.89
5	0	8.00	1667	0	0	177.50	0	-177.5005	57.89	54.79
6	0	8.50	1667	0	0	164.69	0	-164.6857	54.79	51.72
7	96	9.00	1111	78.539	109.65	152.01	0	-152.0108	51.72	49.55
8	248	11.50	1389	203.213	104.275	135.39	89.0444	576.9644	49.55	48.10
9	379	13.42	0	310.8	100.147	123.39	189.587	1393.309	48.10	50.05
10	481	14.67	0	393.966	97.4595	125.87	266.856	2008.972	50.05	52.94
11	546	15.86	1389	447.045	94.901	131.92	316.929	2403.515	52.94	54.29
12	569	18.49	1111	466.419	89.2465	127.38	339.455	2588.259	54.29	56.36
13	550	19.23	528	450.767	87.6555	132.12	326.801	2482.291	56.36	59.16
14	490	20.45	0	401.158	85.0325	137.72	284.513	2138.38	59.16	62.23
15	392	27.00	833	320.971	70.95	125.34	225.019	1674.808	62.23	63.33
16	263	26.00	278	215.67	73.1	132.81	128.313	893.6988	63.33	64.07
17	113	25.94	278	92.4329	73.229	135.66	17.2835	2.610408	64.07	63.44
18	0	24.87	0	0	0	137.22	0	-137.222	63.44	63.02
19	0	22.32	0	0	0	144.80	0	-144.7965	63.02	62.57
20	0	19.43	0	0	0	153.50	0	-153.4981	62.57	62.10
21	0	14.00	944	0	0	171.14	0	-171.1417	62.10	55.56
22	0	12.65	889	0	0	152.67	0	-152.6703	55.56	53.73
23	0	11.41	833	0	0	150.56	0	-150.5631	53.73	51.99
24	0	8.35	0	0	0	155.26	0	-155.2575	51.99	51.51
Total	4128.2	15.6	12916.7			3554.89	2183.8	13915.52		

Table - 3 Solar Thermal Calculation for Summer Condition

Solar Time	Solar Radiation wh/m2	Ambient Temp.(S) ℃	Building Load Wh	Q_{in} Wh/m2	Collector Loss Wh/m2	Tank Loss Wh	Qu Wh/m2	Qu Total Wh	Tank-i ℃	Tank-f ℃
1	0.0	22.50	0	0	0	150.19	0	0	60.00	59.77
2	0.0	21.00	0	0	0	155.28	0	0	59.77	59.53
3	0.0	20.50	0	0	0	156.33	0	0	59.53	59.29
4	0.0	19.50	0	0	0	159.37	0	0	59.29	59.05
5	0.0	18.00	555.556	0	0	164.40	0	0	59.05	57.94
6	55.8	18.50	388.889	45.6649	228.416	157.97	0	0	57.94	57.10
7	207.8	19.00	555.556	170.195	88.15	152.61	73.8405	590.724	57.10	56.92
8	349.4	21.50	0	286.186	82.775	141.88	183.07	1464.56	56.92	58.95
9	471.0	23.42	0	385.734	78.647	142.31	276.378	2211.03	58.95	62.13
10	564.2	24.67	0	462.055	75.9595	150.02	347.486	2779.89	62.13	66.16
11	622.6	25.86	0	509.947	73.401	161.41	392.891	3143.13	66.16	70.74
12	642.4	28.49	0	526.146	67.7465	169.20	412.56	3300.48	70.74	75.54
13	622.2	29.23	0	509.549	66.1555	185.48	399.055	3192.44	75.54	80.15
14	563.2	40.45	833.333	461.288	42.0325	159.02	377.33	3018.64	80.15	83.26
15	469.7	37.00	277.778	384.649	49.45	185.29	301.679	2413.43	83.26	86.26
16	347.8	36.00	833.333	284.858	51.6	201.28	209.932	1679.45	86.26	87.24
17	206.0	35.94	277.778	168.713	51.729	205.48	105.286	842.284	87.24	87.80
18	53.9	34.87	833.333	44.1305	138.316	211.97	0	0	87.80	86.19
19	0.0	32.32	0	0	0	215.76	0	0	86.19	85.86
20	0.0	29.43	0	0	0	226.01	0	0	85.86	85.51
21	0.0	24.00	555.556	0	0	246.37	0	0	85.51	80.93
22	0.0	22.65	833.333	0	0	233.41	0	0	80.93	79.29
23	0.0	21.41	0	0	0	231.82	0	0	79.29	78.93
24	0.0	18.35	0	0	0	242.65	0	0	78.93	78.56
Total	5175.96	26.02	5944.44			4405.53	3079.51	24636.1		

Solar Thermal Calculation

In order to achieve the final result in the table of solar thermal calculation, some basic variables that have to be determined as following:

- Amount of solar radiation for both summer and winter condition which has been already calculated.
- Building load for both summer and winter which can be calculated by this formula: Q=m* Cp* (ΔT) Where Q is building load, cp is water heat capacity, in this case it is equal (4.19) and ΔT is the different temperature between the target and the ambient.
- Outdoor temperature (ambient temperature) which has been already calculated.
- Tank loss which can be calculated by the following formula:
- $Q_{loss}=U_L*(Tif-Ta)$ where: U_L Is U-Value of the tank, Tif is target temperature and Ta is the outdoor temperature.
- Collector loss which can be calculated by the following formula:
- $Q_{loss}=U*\Delta T$ Where: U = 2.15 w/m2 and ΔT is the different between the target temperature and outdoor one.
- Useful energy that could be used which can be determined by the following formula:
- $Q_u = AcF_R(Ha-U_L(T_{if}-Ta) - Q_{loss.}$ Where: Q_u is the total useful energy, Ac is the area of the collector, F_R is the hear removal which = 0.9, U_L is U-value of the tank which is 1.5 w/m2, T_{if} is the target temperature and Ta is outdoor temperature.
- Initial tank temperature which can be determined based on time and location.
- Final tank temperature which can be determined by this formula:
- $Tf = Ti + (dt / (mCp)s) * (Q_u-Q_{load}-Q_{tank\ loss})$, where: Tf is the temperature of the tanks, Ti is the initial tank temperature, m is The tank volume, Qu is the useful energy, O_{loss} is the tank loss energy and Q_{load} is the building load.

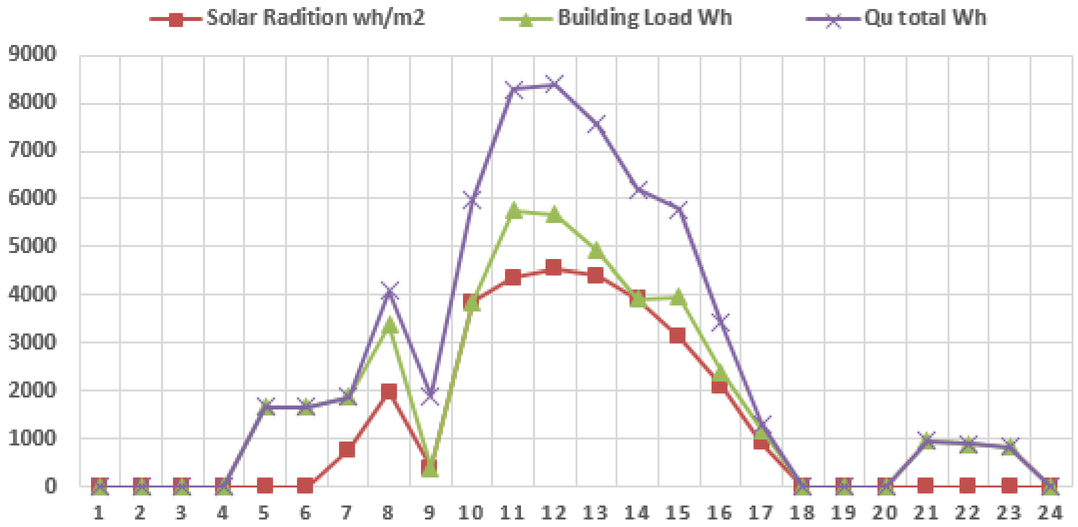

Fig. 8 Solar r, Qu and Building load for winter condition

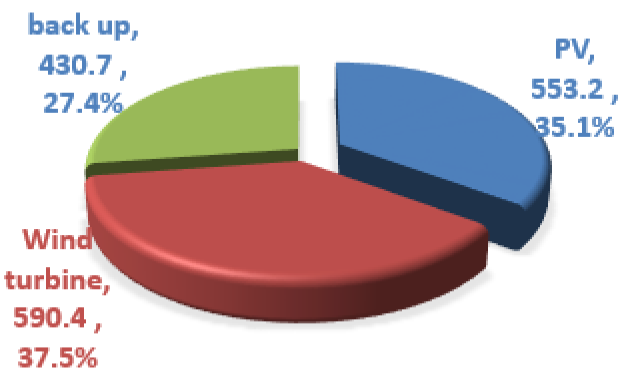

Fig. 9 Energy in summer contributed to Wind turbine, PV, and Backup system

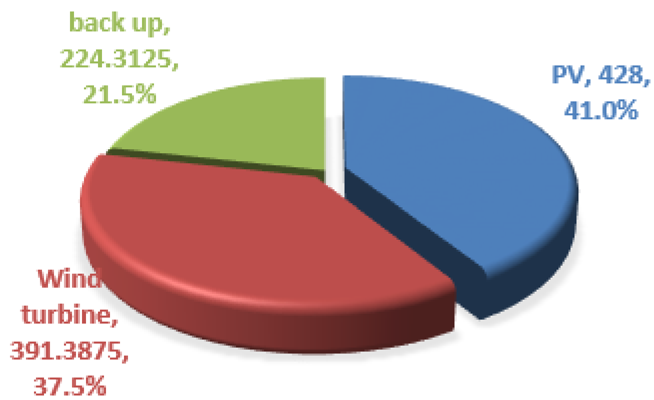

Fig. 2 Energy in winter contributed to Wind turbine, PV, and Backup system

Area and Size of Tank

In terms of the area of the collector, it has been designed to meet the load of winter condition, and the area of the collector is 8m2 as it can be seen in Fig. 8. The reason why it the case of winter has been applied to the area of the collector is because the condition of winter is requiring more hot water so, the size of the tank has to be adjusted with that need. However, in terms of the extra heat that will be produced in summer. There are two different solutions for that. The first one is just to cover the collector which is not really a solution since there is some energy that is not been used. The second selection could be more realistic which is exploit the extra heat to produce a cooling load for cooling proposes as there is an urgent need for cooling in Saudi Arabia. By looking at Fig. 10 which contain the amount of solar radiation, Q total useful and building load for the case of winter, it can be noted that there is a fluctuated in the building load for the need of hot water some of this require during the length of solar radiation and Q useful of the whole area of the collectors. However, some other loads that occur outside that length. For instance, there are some shortages in the early hours before the sunrise and also in a late time before going to bed. In terms of the tank size, height, diameter and area, it has been listed in Fig. 9.

CONCLUSION

The research has investigated the feasibility of using renewable energy technology in Saudi's domestic building. The research has calculated many variables such solar radiation, PV cell temperature, amount of electricity consumed and etc. in order to identify the balanced energy derived from renewable and non-renewable energy sources. It was found that 56% of the energy demand was met in winter with regard to PV system while the percentage was decreased in summer to only 44%. Based on the conducted research, the suggested area of PV can be 6.3^2 instead of 5.10^2. Wind turbine was participated with 37.5% of the total required energy of the house with diameter of 1.65m. With regard to the thermal storage, the area was designed to meet all the required hot water in winter only as summer patter on outdoor temperature is well the above average temperature. Area of collected was found to be $8m^2$. Meeting the required hot water usually found easy. However, this is possible only during daytime, in the evening and at night, it might not be possible to provide the require hot water from the tank. This can be fixed by adopting the behaver of the users to use hot water more during daytime and before 4pm to ensure adequate hot water derived from the tank. It can be observed that renewable energy in housing sector is quite promising and can save considerable amount of energy in the Kingdom of Saudi Arabia.

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