Design of Zero-Energy House for Mangalore Climatic Conditions

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Abstract—**This paper discusses the design of a zero energy off-grid house suitable for Mangalore climatic conditions. As the electricity demands are increasing rapidly, the carbon emissions from the power plants are moving towards the atmospheric threshold value of 410ppm.This makes the concept of zero energy house vital in the current world. In this era, due to the abundant availability of renewable energy-sources like solar and biomass energy, the realization of a zero-energy house is possible with ease. The paper focusses on finding the best suitable building material for the house, the total heat gain inside the house, use of solar vapour absorption system, natural lighting, biomass for cooking and solar PV for operating the necessary power requirements in the house. The size of the house for an average middle-class family in Mangalore is considered for analysis.**

Index Terms—**Bio-mass, heat gain, solar energy, time lag, zero-energy.**

I. Introduction

Zero energy home is the term used for home that optimally combines commercially available renewable energy technology with state-of-the-art energy efficiency construction techniques [1]. Zero energy house is relevant in the current world scenario due to the increase in exploitation of fossil fuels, which leads to higher carbon emission in the atmosphere. Mangalore, located in the southern part of India, is the chief port city of the Indian state Karnataka. The average temperature in Mangalore is 36^{o}C high and 22^{o}C low. Within the past 5 years in Karnataka the electricity consumption has increased by 120% [2]. This proportionally increases the carbon emission in the atmosphere. As the demand for electricity and cost is increasing year by year and due to the extensive losses during transmission, off-grid stand-alone houses give us the most reliant option to fulfil our energy demands. In this paper, the complete design requirements for an off-grid zero energy house situated in Mangalore is considered.

II. Methodology

A. Selection of Suitable Materials for Walls and Windows of the Building

To build a zero-energy house, building bricks and window glass having suitable properties should be selected. Three factors are considered here: Decrement factor, Time Lag and CO_2 emission. The attenuation of heat wave from outside to inside is called decrement factor and the time taken by the heat wave to progress through the wall is called the time lag. The Total Equivalent Warming Index (TEWI) needs to be considered as there is CO_2 emission while manufacturing the building materials as well as while running the air conditioner in the building. Thus, a material having combination of low decrement factor, high time lag and minimum CO_2 emission has to be selected for the construction of buildings.

The types of bricks analysed were ordinary Burnt bricks, Laterite, Concrete, Fly ash lime gypsum (FALG), Soil-cement and Sand-lime bricks. The heat transfer through building wall was assumed to be one dimensional transient heat conduction. A MATLAB code was developed using Finite Difference Method (FDM) to solve the above transient heat conduction problem. ANSYS Transient Thermal workbench was also used to solve the same problem. The boundary conditions imposed were: The inside ambient temperature = 25^{o}C, the inside wall film coefficient = 7W/m^{2}K, the outside wall film coefficient = 23W/m^{2}K, thickness of wall = 25 cm. The results obtained from the MATLAB coding and ANSYS were compared and found to be closely matching.

Total Carbon dioxide emission includes the emissions during production and usage. The CO_2 emission during usage is calculated using the Energy Efficiency Rating (EER) of 4.5 (5 star rated AC), overall efficiency of thermal power plant: 0.25 and CO_2 emission for generation of 1kWh power in thermal power plant: 975grams.

From the analysis, it is found out that FALG is the most suitable material due to its perfect combination of less decrement factor, high time lag and lower carbon emissions compared to other materials. Also, the raw materials of FALG bricks come from the industrial wastes [3] (fly ash from thermal power plants and gypsum from phosphoric acid manufacturing plants), which pose serious disposal problems in India. Thus, usage of these wastes as raw materials would indirectly help the environment. It is also found out that fly ash bricks for walls and grey glass for the windows is the best combination to reduce heat gain inside the house to a significant extent [4].

B. Heat Gain and Cooling Load Inside the House

The study is carried out for a house in Mangalore (12.9141 ° N, 74.8560 ° E, GMT+5.5), one of the coastal cities of India, where the climate is generally hot and humid

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throughout the year. The maximum global radiation received at Mangalore is in the month of April [13]. The analysis is carried out for April 22nd. With the help of a MATLAB code, the total solar radiation incident on the four walls, windows and the door are calculated, followed by the heat gain inside the house and the cooling load on air conditioner.

TABLE I: DECREMENT FACTOR, TIME LAG AND TOTAL CO_2 EMISSIONS FOR DIFFERENT TYPES OF BRICKS

Brick Type	Decrement Factor	Time Lag (Hrs)	CO_2 emission During Production (g CO_2/Kg of Brick)	Indirect CO_2 emission During Usage (g CO_2/Kg of Brick)	Total
Sand Lime Bricks	0.31	4.47	120	50.37	170.37
Laterite Bricks	0.56	5.44	0	31.75	31.75
FALG	0.40	8.16	0	53.44	53.44
Ordinary Bricks	0.55	5.86	270	52.42	323.42
Soil Cement Blocks	0.70	4.0	110	58.5	168.5
Concrete Blocks	0.56	5.31	159	51.68	210.68

1) Geometry and orientation of the house

The length of the house is oriented along the East-West direction, with a door on the east facing wall and two windows each on north and south facing walls.

Dimensions of the house = 10 m × 5 m × 4 m (Length × Width × Height).

Dimensions of the north facing windows = 2 m ×1.5 m × 0.003 m (Height × Width × Thickness).

Dimensions of the south facing windows = 1 m × 0.75 m × 0.003 m (Height × Width × Thickness).

Dimensions of the Door = 2 m × 1 m × 0.03 m (Height × Width × Thickness).

2) Materials used and their properties

TABLE II: PROPERTIES OF BUILDING MATERIALS

Building materials	Thermal conductivity (W/m K)	Density (kg/m^3)	Specific heat (J/kg K)
FALG	0.36	1700	857
RCC	1.58	2288	800

TABLE III: OPTICAL AND THERMAL PROPERTIES OF MATERIALS

Materials	Thermal conductivity (W/mK)	Transmissivity	Absorptivity
Grey glass	1	0.46	0.49
Wood (Door)	0.12	0	0.5
Outer wall	0.7	0	0.54
Outer roof surface	1.58	0	0.6

The above property values are obtained from [4] and the heat transfer data hand book [5].

3) Heat generation inside the house

In a 4-member house, heat generation from the body and different appliances like Television, Electric Iron, Mixer and Biogas is considered, where they are rated 150 W,640 W, 60W, 750W and 90 W of power respectively. It is assumed an average of 20 hours of occupancy inside the home where biogas will be used to cook for 6 hours in a day. The hourly usage of other appliances are obtained from Table VI. The net heat generated in a day is found to be 0.692 kW.

4) Other conditions applied

Outside film coefficient = 23 W/m^{2}K, inside film coefficient = 7 W/m^{2}K and Inside temperature to be maintained = 25^{o}C.

We assume that there is no heat flux coming inside the house through its floor i.e. insulated floor. The heat gain inside the house was calculated with the help of equivalent temperature differential method [6] whose equations were coded and solved in MATLAB.

From Table IV. the heat gain in a day is found to be 59.28 kW hr and the cooling load is 2.47 kW. Considering the heat generation inside the house, the total heat gain in a day is 75.9 kW hr and the total cooling load is 3.162 kW (0.8192 tons).

C. Solar Vapour Absorption Air-Conditioning System

As the aim is to come up with a zero-energy house, the emphasis is given on a grid-free air-conditioning system. Vapour absorption system runs on low-grade thermal energy such as waste heat or solar energy. Since conventional absorption systems use natural refrigerants such as water or ammonia, they are environment friendly. In this system, a pair of water and Lithium Bromide is chosen as refrigerant-adsorbent as the difference between boiling points of the solvent and solution is greater than 300^{0}C and there is no need of dephlegmator and rectifying column as in ammonia-water absorption system.

A basic setup of vapour absorption system is shown in Fig. 1. It works on the principle that addition of non-volatile solute (for example. Lithium Bromide) to solvent reduces the saturation pressure of solvent. In the absorption system, cooling is obtained by connecting two vessels containing solvent and solution respectively. At equilibrium, the pressure being almost same in both the vessels, temperature of the solvent will be less than that of the solution and hence, the refrigeration effect is produced at the solvent which evaporates by taking heat from the surrounding and flowing to the solution vessel where is absorbed by the solution. This process is continued as long as the composition and temperature of the solutions are maintained [10].

A: Absorber; C: Condenser; E: Evaporator; G: Generator; P: Solution Pump; SHX: Solution HX; ER: Refrigerant Expansion Valve, ES: Solution Expansion Valve.

TABLE IV: HEAT GAIN IN W HR THROUGH DIFFERENT WALLS, WINDOWS AND THE DOOR AT AN INTERVAL OF 1 HR

Time	North wall	South Wall	East Wall	West Wall	Top Wall	North Windows	South Windows	Door
0:00	533.78905	545.81958	299.6223	299.62231	1115.502	95.06938293	23.76734573	33.41734
1:00	473.4745	485.50503	269.465	269.46504	1038.77	63.37958862	15.84489716	33.10105
2:00	253.90643	265.93696	159.681	159.681	1038.77	63.37958862	15.84489716	33.10067
3:00	227.17926	239.20978	146.3174	146.31742	962.0377	63.37958862	15.84489716	33.69874
4:00	209.01354	221.04406	137.2346	137.23456	962.0377	31.68979431	7.922448578	33.90803
5:00	209.01354	221.04406	137.2346	137.23456	962.0377	31.68979431	7.922448578	33.93062
6:00	190.84782	202.87834	128.1517	128.1517	885.3058	66.90812184	20.39433061	33.71755
7:00	190.84782	202.87834	128.1517	128.1517	885.3058	192.2459211	120.7120291	32.94192
8:00	190.84782	202.87834	128.1517	128.1517	885.3058	254.4517455	124.3666146	32.84751
9:00	172.6821	184.71262	119.0688	119.06884	808.5739	298.9201871	108.7735761	32.78334
10:00	172.6821	184.71262	119.0688	119.06884	808.5739	368.6028478	101.4321846	32.78334
11:00	172.6821	184.71262	119.0688	119.06884	887.0138	403.3404278	108.2304216	32.71917
12:00	154.51638	166.5469	109.986	109.98598	1009.077	404.2592938	114.2946613	32.71917
13:00	154.51638	166.5469	109.986	109.98598	1100.581	403.3404278	108.2304216	32.71917
14:00	173.08646	185.11699	119.271	119.27102	1183.499	400.2926422	109.3546332	32.655
15:00	201.98412	214.01464	133.7198	133.71985	1340.014	393.98957	132.5409219	32.655
16:00	223.64693	235.67746	144.5513	144.55126	1796.869	349.5211284	148.1339604	32.655
17:00	243.27707	255.3076	154.3663	154.36632	1418.666	287.315304	144.4793749	32.59083
18:00	280.33083	292.36136	172.8932	172.89321	1418.221	193.6672991	52.08412492	32.59083
19:00	388.48813	400.51866	226.9719	226.97185	2133.358	158.4489716	39.61224289	32.65643
20:00	298.95113	310.98165	182.2034	182.20335	2383.616	126.7591772	31.68979431	32.75851
21:00	298.84582	310.87635	182.1507	182.1507	2410.62	126.7591772	31.68979431	32.83503
22:00	468.14933	480.17985	266.8025	266.80245	2155.852	95.06938293	23.76734573	32.90438
23:00	527.39614	539.42666	296.4259	296.42586	1228.397	95.06938293	23.76734573	33.03527

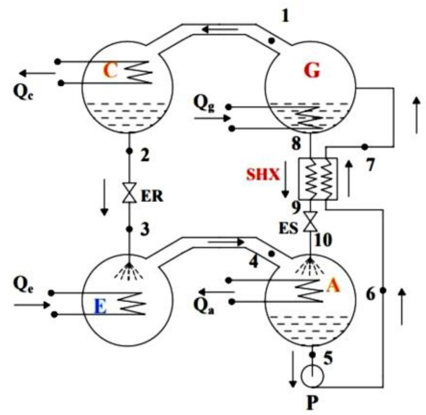

Fig. 1. Schematic diagram of a H20-LiBr system [10].

TABLE V: THE OPERATING CONDITIONS OF AIR-CONDITIONING SYSTEM

State point	Temperature (in ^{0}C)	Pressure (in kPa)	Mass fraction	Enthalpy (in kJ/kg)
1	80	7.3	-	2651.4
2	40	7.3	-	167.53
3	15	1.7	-	167.53
4	15	1.7	-	2528.3
5	40	1.7	0.52	-150
6	40	7.3	0.52	-150
7	76	7.3	0.52	-78
8	80	7.3	0.58	-85
9	40	7.3	0.58	-166
10	40	1.7	0.58	-166

The comparison of vapour absorption system and vapour compression system with R134a as a refrigerant is done for 1 Ton refrigeration capacity. Following formulae were used [7].

For Absorption System,

$$m = \frac{Q_e}{h_4 - h_3} \tag{1}$$

$$Q_g = mh_1 + m_{SS}h_8 - m_{WS}h_7$$

$$W_{pump} = (1+\lambda)m \times V_{sol} \times (P_c - P_e)$$

For Compression System,

$$m = \frac{Q_e}{h_1 - h_4} \tag{2}$$

$$\eta_{is} = (h'_2 - h_1)/(h_2 - h_1)$$

By using equation (1), it is found that the power required to run a compressor (65% isentropic efficiency) in a compression system is 497.11 W and for an absorption system to run a solution pump is about 0.044W. Hence the vapour absorption system is more appropriate for zero energy house. Thermal energy required for operating the generator was found to be 3.95 kW for 1 Ton refrigeration and is to be provided by using solar flat plate collector. Collector plate area is calculated by using the following formula [8],

$$A_c = \frac{Q}{\eta \times I} \quad (3)$$

By using the equation (3) and substituting collector efficiency (η_c) of 0.55 [9] and solar radiation intensity (I) of 675W/m^2 [13], area (A_c) is calculated as 10.65 m^2.

D. Natural Lighting

The sun provides a maximum illuminance of 100 kilolux on a clear day. Due to the abundant availability of natural sunlight during the day time, the aim is to bring that light into indoors, to reduce the usage of bulbs. The natural light illumination system can be divided into collecting, transmission and lighting components [11]. For collecting sunlight, static light concentrator having a prism like structure is used. Incident sunlight reaching the top surface undergoes reflections and refractions. The output ray passes through the optical transmission unit. Optical transmission unit consists of a coupler and optical fibres in a light pipe. The coupler is used to enhance the efficiency of light guided into the fibre. The light passes through the optical fibre following Total Internal Reflection (TIR). To distribute the light evenly inside the room, the TIR needs to break. The National Taiwan University of Science and Technology Electronics department experimentally analysed different types of dot patterns that can efficiently distribute the light. They derived 91% coupled efficiency with the designed coupler and fibre. An optical switch was also designed using a reflecting surface in the cubic structure. This can be used to charge solar cells or rechargeable LEDs to reduce the power requirement at night [11].

In Mangalore, experimentally we found out that at noon, when the sun has an altitude angle of 80^o, the maximum illuminance observed near the window was 1900-2010 lux. The recommended light levels indoor for homes and for reading varies from 150-250 lux [12]. The house can be designed in such a way that the study areas and office desks are in close proximity to the windows. Light pipes can be directed to light the corridors and corners of the house, where windows aren't present. Consider 4 rooms in the 50 m^2 house. Each room size will be around 12.5 m^2. When the sunlight is strong, 5 light pipes each having an average of 1500lm, with a 50% efficiency, will produce 60 lux per pipe. According to recommended levels of light, 20-100 lux is sufficient.

E. Solar Photo-Voltaic System

For a stand-alone house, to meet the energy requirements for various appliances, Solar PV is considered. The region between the latitude of 40^{o}N and 40^{o}S is generally known as Solar Belt and has abundant solar radiation [13]. Mangalore being located at 12.9141^{o}N, geographically favours solar harvesting. From the climate report of Mangalore, it is found out that average sunshine hours obtained per day is 7.7 hours, maximum being in the month of January [14]. The average global radiation received in Mangalore is 690 W/m^2[13]. The standard test conditions at which the PV is tested is 1000 W/m^2, which is the maximum radiation that can be incident on the face of the Earth. The panel generation factor is calculated as,

$$\text{Panel Generation Factor} = \frac{\text{Sunshine Hours} \times \text{Available Radiation}}{\text{Standard Test Condition Radiation}} \quad (4)$$

From equation (4), Panel generation factor is found to be 5.313. Based on the results of a survey conducted in more than 1000 households in four districts of Karnataka, the commonly used appliances in houses were found out [15]. It is further optimized by choosing the best alternate appliance available in the market for our home.

TABLE VI: OPTIMIZED ANNUAL ENERGY CONSUMPTION OF HOUSEHOLD APPLIANCES

Sl. no.	Appliance	Rating (Watt)	Numbers	Usage (hr/day)	Usage (hr/yr)	Consumption (kWh/yr)
1	LED Bulb	9	6	4.5	1642.5	88.695
2	Fan	30	2	2.71	989.15	59.349
3	Electric Iron	750	1	0.67	244.55	183.412
4	Mixer	450	1	0.47	172	77.20
5	Refrigerator	100	1	22.33	8150	815.05
6	Television	79	1	3.93	1434	113.286
7	Water Pump	370	1	0.68	248	91.834
8	Battery Charger	5	2	3.25	1186	11.86
	Total	2198				1440.89

In Table VI, the hours of usage for LED bulbs are restricted to night time as natural lighting will be provided during the day time. Considering 30 days in a month, the total daily consumption of energy in the house is found to be 4 kWh. The pump requirement for Solar Vapour Absorption System is 0.044 W, which can be considered negligible. Using this knowledge, the minimum power requirement is calculated using the formula [16],

$$W_P = \frac{\text{Total Energy Demand}}{\text{Panel Generation Factor}} \times \text{Margin} \quad (5)$$

Here, margin is taken as 1.2. Using equation (5), 903.45 Wp is obtained. SunPower® Solar panel of 335W nominal power, 21% efficiency, 67.9V open circuit voltage and 6.23A short circuit current is selected. 3 such panels are required to satisfy the power requirement. A stand-alone house requires four major components to use solar PV electricity in homes. PV array, Charge Controller, Battery Bank and Inverter and Distribution Panel. A charge controller regulates the flow of electric current to and from the battery to avoid over charging and over voltage, which can reduce the life of a battery. Since the panels are connected in series, the maximum voltage will be 67.9 × 3 = 203.7V. Charge controller of Maximum open circuit voltage 250V and operational voltage of 12/24/48 V is chosen having 98.9% of Maximum Power Point Tracking (MPPT). Fixing the operational voltage as 24V, the minimum battery capacity is calculated using the following formula [16],

$$\text{Battery Capacity}=\frac{\text{Total Energy Demand}\times\text{Margin}\times\text{Days of Autonomy}}{\text{Depth of Discharge}\times\text{Operational Voltage}} \quad (6)$$

(Since Lithium Ion batteries have more life expectancy, it is chosen. The depth of discharge is 85% and marginal loss is 1.2. In equation (6), Days of Autonomy refers to the number of days the battery will be functional without being recharged. It is assumed as 2 days. Using equation (6), minimum battery capacity is found to be 470.58Ah. A battery of 12V and 100Ah capacity is chosen. Then 2 batteries need to be connected in series and 5 batteries should be connected in parallel giving the total number of batteries as $5\times2=10$ batteries. For a stand-alone house, the invertor depends on the total wattage of the house. From the Table 6., the total wattage is found to be 2198W/day. For 90% efficient invertor, the minimum nominal power rating is 2442.23W. An invertor by iMeshbean® of 2500W rating and 24 VDC to output of 240 VAC is selected. It is stackable and hence can increase the power output by connecting in parallel if required. Using Solar Energy Data handbook, the optimum tilt angle of solar panels with respect to vertical is found to be 100^o facing South, 54^o and 77^o facing North, for Summer, Winter and Spring/Autumn seasons [17].

F. Bio-Gas

Due to the energy crisis caused by over consumption of fossil fuels, the world is in need of a green, efficient, carbon- neutral energy source to replace them. Kitchen waste is found to have a higher potential to produce biogas than cow dung. The amount of waste generated from the kitchen is found to be of sufficient quantity to generate enough biogas to use in the kitchen for cooking. This biogas generated is mainly composed of 50% to 70% methane (CH_4), 30% to 40% carbon dioxide (CO_2) and low amount of other gases [18].

As per Advisory Board of Energy (ABE), average requirement for cooking in India is 620 kcal per capita per day of useful energy [19]. The main source of energy was mainly liquefied petroleum gas (LPG) which is very expensive.

1) Comparison of energy spent per capita per day for cooking through LPG and biogas

After the LPG subsidy scheme by govt. of India, it is reported that 89% of families with 5 members per family use 7 LPG gas cylinders of 14.2 kg net gas each per year to suffice their energy requirement for cooking [20]. And it's known that specific calorific value of LPG is 46.1 MJ/kg [21]. Hence,

Amount of energy required per day per capita for cooking through LPG = $46.1 \times 7 \times 14.2 \times 5 / 365$ = 2.51 MJ = 599.294 kcal.

A daily quantity of 2 kg organic waste with leftover food as well as vegetable waste and fruit waste will be generated by a 5-member household [22]. This 2 kg of kitchen waste is fed to the biogas digester.

Gas production rate (G): One kilogram of kitchen waste, if well digested yields 0.3 m^3 of biogas [18]. The biogas production rate (G) for the available kitchen waste, working with 2 kg/day is found to be 0.6 m^3/day. Calorific value of biogas produced by kitchen wastes is found to be 23 MJ/m^3 [23].

So, energy generated per capita per day through Bio-waste = $0.6 \times 23/5$ = 2.76 MJ = 658.756 kCal.

Therefore, biogas can suffice the energy requirement of cooking by producing more energy than LPG when calculated per capita for both the cases.

2) Design based on end-use-substitution of biogas for cooking

Design of biogas plant will be done for 5 houses of 5 members each for spatial, material and economic feasibility. In order to maximize biogas production, the kitchen waste and water should be fed in 1:2 ratio into the digester [24]. So, for 2kg kitchen waste, 4litre of water is to be fed.

The active slurry volume in the digester is directly related to the hydraulic retention time (HRT). This is the theoretical time that a volume of liquid waste added would remain in the digester.

Active slurry volume is therefore given by

$$V_S=\frac{\text{HRT}\times2\times W}{1000} \quad (7)$$

For the kitchen waste, HRT=30 days [18]. From equation (7), active slurry volume is found to be Vs=1.8 m^3. (5 houses with 2kg kitchen waste and 4lt water i.e., 6kg of feed). For design simplification, the standard volume 2 m^3 which is nearer to calculated volume is selected. [25]

The relative values of height and diameter can be calculated from the volume of the digester given by,

$$V_S=\left(\frac{\pi}{4}\right)\times D^2\times H \quad (8)$$

In practice the ratio of D/H is taken as 2 [17].

TABLE VII: MATERIALS REQUIRED FOR CONSTRUCTION OF SOLID-STATE BIOGAS PLANT: [25]

Material	Brick	Cement	Concrete (3/4")	Sand	GI pipe, nipple with socket	AC pipe	Epoxy Paint
Unit	Nos.	Bag	Cubic meter	Trolley	Set	Litre	meter
Quantity required	1000	15	1.25	1.2	1	10	1.5

Therefore, from equation (8), height of digester, H=0.8602m and diameter of the digester, $D=2\times0.8602=1.7204$m. For a proper alignment in a movable drum type plant, it is an appropriate design practice to keep gas holder diameter smaller by 6 inches (.1524m) less than that of digester [24].

Diameter of gas holder should therefore be =1.568m. So, height of the gas holder = (Volume /Area) = 0.9326 m. The Surface Area is calculated as the sum of the area of digestor bottom, gasholder bottom and the annular space between the digester and gas holder. The surface area required is found to be 4.5383 m^2.

For a middle-class family, the plan should be economical. Deenbandhu biogas plant is considered, which has a fixed dome type economical plant with less initial cost and better payback period. It consists of an inlet, mixing chamber, digester, gas holder and outlet chamber for slurry. It works on the principle of production of biogas by anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material and energy crops. The design consists of 2 spheres of different diameters, joined at their bases. This spherical design mainly nullifies the earth pressure and reduces the surface area required, which in turn minimizes cost of the biogas plant. Also, the structural strength of the spherical structure is comparatively more [24].

III. Results and Discussions

For designing a zero-energy house, a wide pool of materials and their properties were considered. FALG turned out to be the most viable out of them as it has very less thermal conductivity and leaves less carbon footprint. Further, after performing the heat gain analysis of the building for 24 hours on each wall, total heat gain of 75.9 kWh (0.8192 tons) was obtained. The heat gain inside the building for two different building materials i.e. ordinary brick and FALG, were 3.37 kW and 2.47 kW respectively. Hence FALG bricks leads to lower cooling load for air conditioning system. After comparing the energy input requirements of pump and compressor of vapour absorption system and vapour compression system, it is clear that vapour absorption system is more suitable. Also, water is used as refrigerant in vapour absorption system which is eco-friendly. An absorption system of 1 Ton refrigeration capacity (3.5 kW) is found to be appropriate for the project. But the system of minimum refrigeration capacity available in the market is 10 Ton. So, 10 Ton refrigeration system will be used in a community of 10 houses. The total energy consumption of basic household appliances was found out and optimized, comparing with the best alternatives available in the market. From calculations, a total of 120 kW units was obtained per month. For an average of 7.7 sunshine hours, 3 solar panels each of 1.1 m^2 can be installed on the rooftop of the house for better results. A charge controller of maximum operational voltage 250V, 10 batteries each having 100Ah current and 12V voltage and an invertor of 2500W with 24 VDC to 240 VAC conversion is found to be ideal for the operation. A tilt angle of 100^o towards North in summer and 54^o, 77^o towards South in winter and spring/autumn with respect to the vertical is found to be ideal for Mangalore. This study has shown that biogas production through organic waste not only meets our daily energy requirement, but also reduces the problems regarding solid waste management. For cooking through LPG, it is found that the present energy consumption per capita per day is around 599.29 kCal in theory. Whereas, around 658.75 kCal of useful energy generation per capita per day is possible even for a person in a middle-class family in India. Around 4.54 m^2 surface area of small-scale biogas plant is required for a community of 5 houses, which can be easily obtained in the backyard of home. Combining all the above design factors, a zero-energy house can be built.

IV. Conclusion

At the present rate of advancements in renewable technologies, net zero-energy houses will be our future reliance. Due to increase in the day to day consumption and demand of energy, zero energy buildings will be prominent for energy efficient constructions, which has better thermal comfort as well as eco-friendly nature. The efficiencies may vary under various climatic conditions, when the procedures are practically performed. Zero energy homes can be designed using new scientific techniques like solar glass, to increase the solar-energy input and phase change materials on walls, to improve the thermal mass. But the goal of zero energy buildings is not far from reality. When regions like Scandinavian countries have already deployed these techniques in large scale constructions, there is a need to spread awareness about the advantages of zero energy buildings. A laboratory simulation model will be done and the results will be compared with the theoretical results.

Nomenclature

λ − Circulation ratio
h'_2 − Enthalpy at compressor outlet in actual process
h_2 − Enthalpy at compressor outlet in isentropic process
h_1 − Enthalpy of refrigerant at evaporator/generator outlet
h_3 − Enthalpy of refrigerant at evaporator inlet
h_4 − Enthalpy of refrigerant at evaporator outlet
h_7 − Enthalpy of solution at generator inlet
h_8 − Enthalpy of solution at generator outlet
LED – Light Emitting Diode
LPG − Liquified Petroleum Gas
m − Mass flow rate of refrigerant
m_{ss} − Mass flow rate of strong solution
m_{ws} − Mass flow rate of weak solution
P_c – Condenser pressure
P_e – Evaporator pressure
PV − Photo-Voltaic
Q_e – Refrigeration Capacity
Q_g – Heat required to run the generator
$W_{isentropic}$ – Work to be supplied to compressor if the compression process is isentropic
W_{actual} – Work to be supplied to the compressor in actual process
η_{is} − Isentropic efficiency

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