JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue

JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)

An International Scholarly Open Access, Peer-reviewed, Refereed Journal

DESIGN OF SOLAR POWER SYSTEM FOR SELF-SUSTAINABLE VILLAGE

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Abstract : **India is the third-largest consumer of energy in the world. India is a developing nation, and its demand for energy is always rising. In this nation, fossil fuels are the main energy sources. A switch from fossil fuels to non-conventional energy is necessary as they grow more expensive, harder to find, and have other drawbacks. Solar energy is abundant, and it may be used to produce power. With an increase in the area under the agriculture sector and the improved living style/standard of the rural population, the requirement for electricity in rural areas increased. This study focuses on the need for electricity in villages. The study area is located at Khadakwadi, Taluka Parner, Dist. Ahmednagar. Detailed information about the consumption of electricity in households and Agriculture is collected. To fulfil the village's electricity demand with solar power, the required area, cost, and the design of the solar plant will be analyzed. The study will focus on the possibility of a reduction in conventional electricity charges for each household and farmer by switching to solar-powered equipment. From the study it was observed that with a growing family, there is an increase in electricity use. The highest electricity consumption was found in the month of May. The lowest electricity consumption was found in the month of December. Thin film -Cadmium telluride (CdTe) material was found to be the best and most efficient for manufacturing solar panels. This prototype can be useful for a self-sustainable village model using solar energy.**

Index Terms **-** Solar Energy, Electricity, Government Subsidy, Energy Consumption

1. INTRODUCTION

Sustainable energy comes from resources that can support present operations without endangering the energy demands or climate of future generations. The most well-known sustainable energy sources include wind, solar, hydropower, etc. Other industries including agriculture, pottery, weaving, and carpentry may be powered by solar energy in rural India. Renewable energy sources play a vital role in securing sustainable energy with lower emissions; People can also seek employment and improve their skill sets in these sectors (Majid, 2020). With global warming and environmental pollution reaching hazardous levels daily, solar power is essential. It is a free and limitless source of energy, and panels are not only simple to install but also the answer to global warming. As a result of these initiatives, the economic health of the communities will improve. Numerous eco-villages already in existence can achieve sustainable energy while also providing a competitive alternative to traditional fossil fuels like coal, oil, natural gas, and nuclear power by incorporating concepts for renewable-based energy supply.

An effective use of smart grid technology to enable energy-independent eco-villages is the management of a small grid with considerable renewable energy output. Several energy-self-sufficient eco-villages have been constructed using the intelligent grid idea (Pramanik, 2005; Bonifazi et al., 2013; Kang, 2014). Following China (26.83%), the USA (14.36%), and the EU (9.66%) in terms of global carbon emissions, India ranks fourth with about 6.65% of the total. According to official data from the Indian ministry of new and renewable energy, over 5,000 trillion kWh of energy are incident over the country's surface each year, with the bulk of places receiving 4–7 kWh per square metre each day. One of India's major initiatives is the National Solar Mission, which has solar energy at its core and is one of the key missions in the country's National Action Plan on Climate Change. On January 11th, 2010, the National Solar Mission (NSM) was sent into orbit. The National Sustainable Mission (NSM) is a significant programme launched by the Indian government to support environmentally friendly growth and solve the country's energy security concerns. It is possible to successfully capture solar photovoltaic energy, giving India enormous scalability. India just passed Italy to rise to fifth place worldwide in the utilisation of solar energy (Singh et al., 2020). Between March 2014 and July 2019, solar power capacity expanded by more than 11 times, from 2.6 GW to 30 GW. Solar energy is used in rural regions to run small enterprises, light up clinics and schools, dry crops, pump water for irrigation, and promote health.

Sustainability and renewable energy are related in a hierarchy of objectives and limits that take into account both global and local factors. In fact, the Earth absorbs solar energy at a pace that is 10,000 times higher than the rate at which people use electricity (Sen et al., 2016). Although not every nation has the same amount of solar energy resources, practically every nation has the potential to add large amounts of direct solar energy to its energy mix. There is currently little data to support the significant influence of climate change on local solar resources. Currently, an established technology, solar hot water heating for residential and commercial buildings is used in the majority of the world's nations and is expanding at a pace of approximately 16% annually.

Considering this research gap, the objectives of this study are:

1) To estimate the impact of solar energy in a rural context.
2) Implement a self-sustainable village concept using solar energy for electricity generation.

2. MATERIALS & METHOD

2.1 Study Area

The study site is located at Khadakwadi, Taluka Parner, Dist Ahmednagar, Maharashtra. The geographical location of the Study area can be expressed from 18°32'0" N latitude and 76°15'0" E longitude. It is located 51 KM to the west of the district headquarters of Ahmednagar. Khadakwadi Village Total population is 3135, and the number of houses is 655.

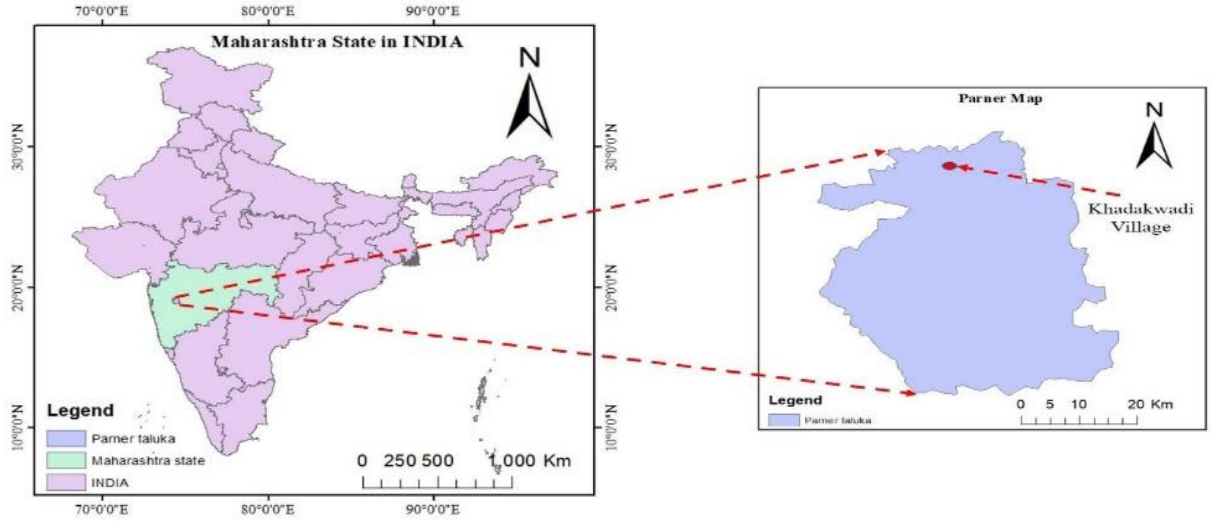

Fig.1. Location of Khadakwadi Village

2.2 Data Collections

The data for this study is collected from the survey in the form of google sheets and physical interviews conducted in the selected village. Randomly selects 50 houses from the villages, which includes small family (2 family members), (3 member family) and large family (more than 4 family members). Also, governmental buildings such as Gram panchayat, Primary schools, High schools, milk collection centres, and shops were included in the data collection.

Fig.2. Pictures clicked while collecting data in Khadakwadi Village (source – Author)

2.3 Materials Used for Solar Panels

There are many methods for renewable sources of energy, but we are focusing on solar power. There are too many ways in solar energy by which we can produce and use the energy for various activities like cooking, lightning, agriculture, etc. We can produce or generate energy with photovoltaic cells, solar heating, solar cooking, etc. In rural areas, Current sources available for cooking are firewood, crop residues, and animal dung. Promoted by the Ministry of New and Renewable Energy, the Government of India are Solar Cookers, Solar Box Cookers, Community Solar Cookers, Solar Steam Cooking Systems, etc.

Several different materials are used in the production of solar cells. Different types of materials are used in the creation of thin-film solar panels. Cadmium telluride is the primary component of the thin film solar cell (CdTe). CdTe is sandwiched between the thin-film panels during production, helping to capture solar energy and convert it to electricity. To shield the solar panels from harm, they also feature a glass covering on top.

The best solar cell-based gadget is composed of cadmium telluride (CdTe). Compared to standard silicon-thin cells, they are far more affordable. A number of tiny layers make up cadmium telluride (CdTe) panels. Compound cadmium telluride and its surrounding layers for electricity conduction and collecting are one of the primary components. These solar cells have up to 18% efficiency on record.

Crystalline silicon is used to create amorphous solar panels, which have a 22% efficiency. They have several construction methods. They are created by depositing nanocrystalline silicon on a substrate consisting of glass, metal, or plastic in place of silicon wafers. The solar panels have one silicon layer that may be utilised as a thin micrometre. Solar cells made of gallium arsenide (GaAs) have a 30% efficiency. But making them is expensive. They are mostly utilised in satellites and spacecraft.

2.3.1. Thin-Film Solar Panels Advantages

Low material use is a feature of solar panels. They are both extremely effective and environmentally friendly. It is determined how well solar panels convert solar energy into electricity by measuring their efficiency. More efficient solar panels are those that occupy less area on the roof. If upgrading to a solar energy system is appropriate for your house or business structure, it will depend on a number of criteria, including panel arrangement/angle of installation, geographic location, the architectural style of your roof, heat gain, and the amount of shade on your building. The price of installation varies depending on where it is done.

By dividing the total solar energy produced by the solar cells by the amount of sunlight received in a particular area, the efficiency of solar panels is determined. The majority of solar panels vary from 14% to 16% efficiency, while the most efficient ones on the market have an efficiency of 18.5-22.5%. The greatest solar panel efficiency ever is 46%. A portion of the energy is reflected by the panels, and occasionally an electron is released that returns to the hole.

2.3.2. Various Technologies in the Solar Panels and their Efficiency Rates

Following are the available technologies for solar panels and their efficiency rates:

A) Crystalline Silicon – Monocrystalline solar panels (up to 22%) and Polycrystalline solar panels (up to 20%); B) Thin Film (up to 16–17%); C) Multi-crystalline (up to 45%); D) Organic solar cells (<10%).

Solar panels are made in India by several companies. In India, two different kinds of producers, however, advertise their goods. First, there are the national or Indian brands, followed by the foreign or worldwide brands. If you're from India and want to put solar panels in your home, you must get them from us because the government's subsidy only applies to Indian companies.

Table 1. The major difference between Monocrystalline Solar Panels and Polycrystalline Solar Panels

Points of Difference	**Monocrystalline Solar Panels**	**Polycrystalline Solar Panels**
Colour	Monocrystalline Solar cells are of black-hui in color	Polycrystalline solar cells are of a blue-is hue
Cost	The cost of these solar panels is expensive	The cost of these solar panels is less expensive
Efficiency	Monocrystalline Solar Panels are more efficient than Polycrystalline Solar panels	Polycrystalline Solar Panels are less efficient
Lifespan	The life span of these solar panels is a minimum of 25 years	The shelf life of these solar panels is up to 25 years

There are companies like Indosolar, Moserbeer, RenewSys, etc. that are well-known for having reasonable solar prices in India. The cost of solar panels is primarily influenced by a number of elements, including the material they are built of, the features and functions they have, how much electricity they use, and many more. The costs of solar panels for residential use also depend on additional uses, such as solar fans, solar air conditioners, solar lighting, and solar water heaters. Solar panels that produce 2.5 KWh/day generate 8 hours of sunshine. Solar panels are produced for 900 KW hours annually, which is ideal for using a variety of appliances like TVs, laptops, LED lights, etc.

One of the top nations for installing the most solar panels worldwide is India. We were encouraged to install solar panels by our government, whether for residential or business use.

3. Results and Discussion

3.1. Monthly variation in Electricity Consumption of Different Users

From the collected data on electricity consumption, the data is sorted according to different users which includes 2 members family, 3 members family, and large family (4 or more family members), shops (which includes shops, private industry, government offices, etc.) and agricultural users which includes electric pumps, chaff cutter, etc. Individual analysis of different users is discussed in the following subsections.

3.1.1. Two Members' Family

The monthly variation in electricity consumption of 2 member families was shown in fig. 2. From the figure it was observed that some families' electricity consumption is nearly the same throughout the year. One family (2m_2) has found the highest variation in the month of May. The reason behind the highest electricity consumption is the family function held during the month of May. From this, it was clear that electricity consumption varies with the living standard of the family.

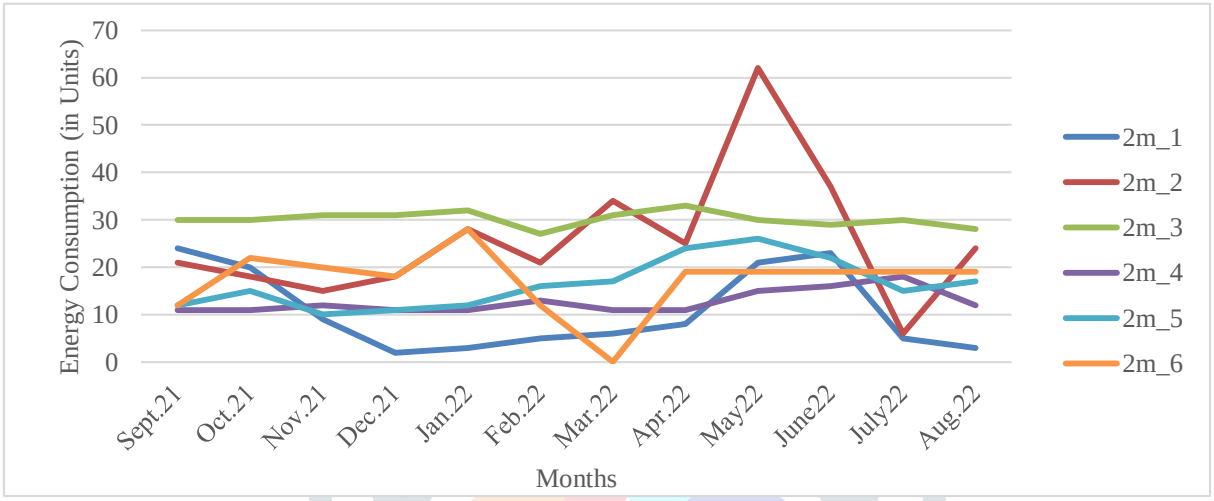

Fig. 3. Variation in Electricity Consumption of 2 Members Family

3.1.2. Three Members' Family

The monthly variation in electricity consumption of 3 member families was shown in fig. 3. From the figure it was observed that some families' electricity consumption is nearly the same throughout the year. The Recorded Average electricity consumption members' families was 30 units per month.

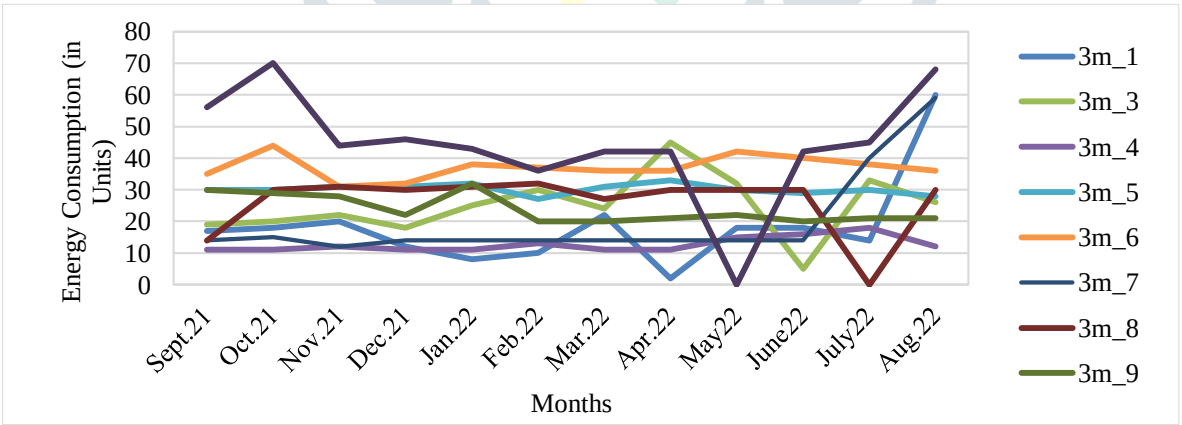

Fig. 4. Variation in Electricity Consumption of 3 Members of Family

3.1.3. Large Family (More than 3 Members)

The monthly variation in electricity consumption of large families was shown in fig. 4. From the figure it was observed that some families' electricity consumption is nearly the same throughout the year. But some families have shown a very high variation in electricity consumption throughout the year. Also, there is a peak in the electricity consumption (above 80 units per month) graph in the summer months. The reason behind this is the use of household equipment like refrigerators, AC, mixers, fans etc. The Recorded Average electricity consumption for large families was 45 units per month.

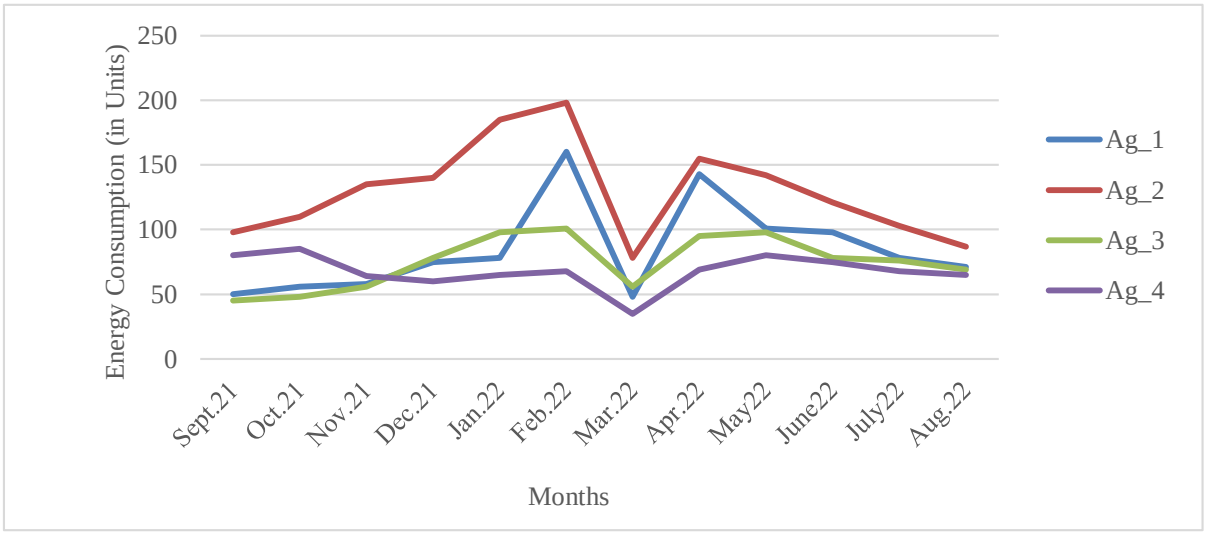

Fig. 5. Variation in Electricity Consumption of Large Families

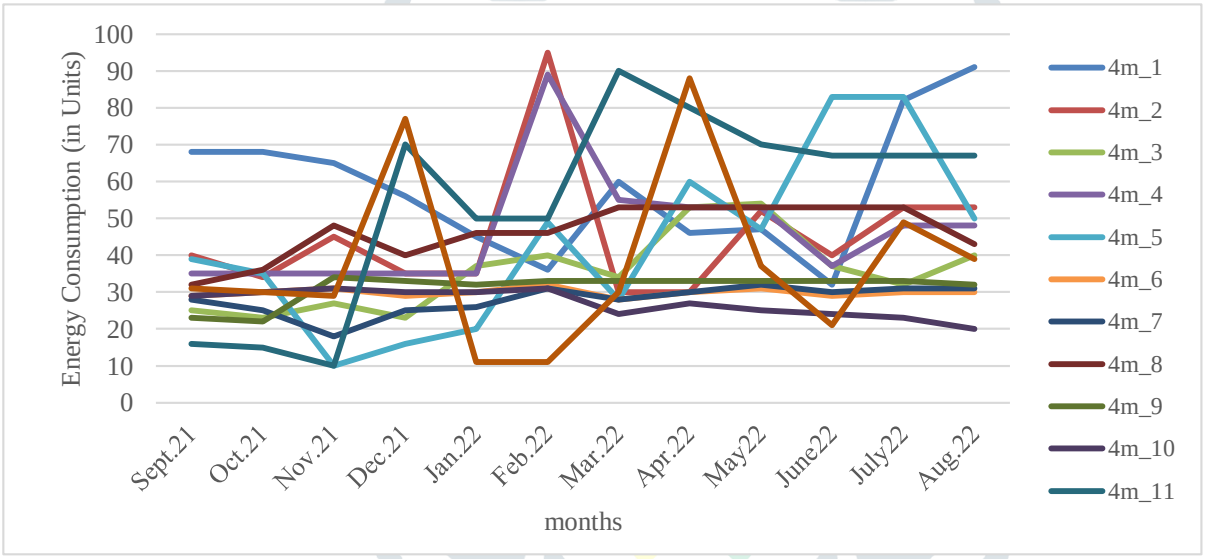

Fig. 6. Variation in Electricity Consumption of Shops

3.1.4. Shops

The monthly variation in electricity consumption of different shops was shown in fig. 5. From the figure it was observed that some shops' electricity consumption was not the same throughout the year. The electricity consumption was found to be highest in the summer months and highest in May month. The shop has a daily milk collection center, and it has found the highest electricity consumption due to the use of heavy milk storage tanks, coolers and other heavy equipment. The Recorded Average electricity consumption for Retail shops was 150 units per month.

3.1.5. Agricultural Users

The monthly variation in electricity consumption of agricultural users was shown in fig. 6. From the figure it was observed that some families' electricity consumption was not the same throughout the year. The highest electricity consumption was observed in the summer months. Also, it was observed that March month has suddenly declined in the use of electricity consumption because in the month of March there was a canal rotation for irrigation purposes. So all agricultural users use the water from the canal and use electric pumps for this month suddenly declined. Also from November to March month in the agricultural field major growing crop is Onion and nearly 90 % of users grow onion, so irrigation is required throughout the growing period. The recorded average use of electricity for Agricultural purposes was 60 units per month.

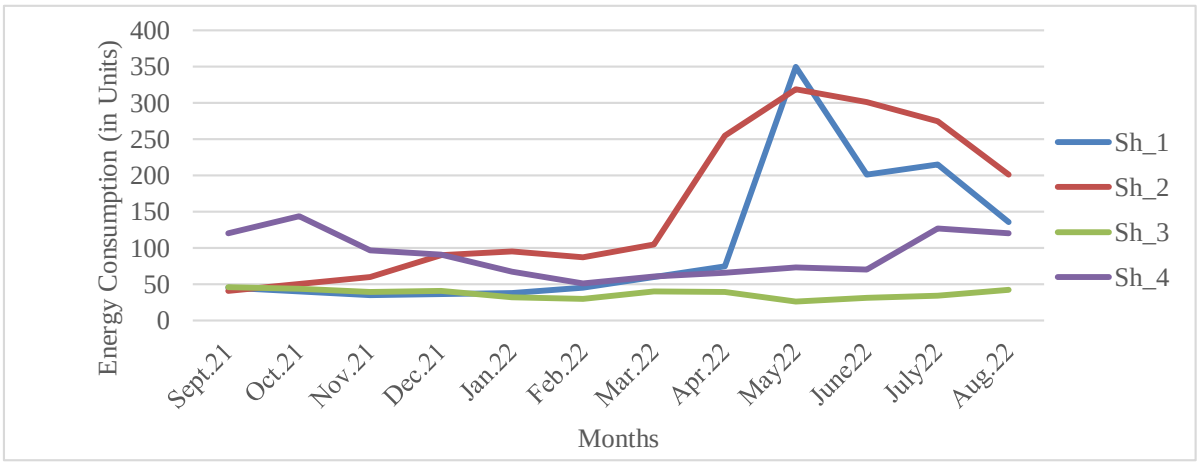

Fig. 7. Variation in electricity consumption of agricultural users

3.2. Comparison of Electricity Consumption of Different Users

Collected data were analyzed for comparison between the selected different electricity users. It was observed that small-size family uses less electricity as compared to other users (Fig. 7). The shop has a daily milk collection center, and it has found the highest electricity consumption. A large family has more electricity consumption as compared to a small family. The Recorded Average electricity consumption for all users was 60 units per month.

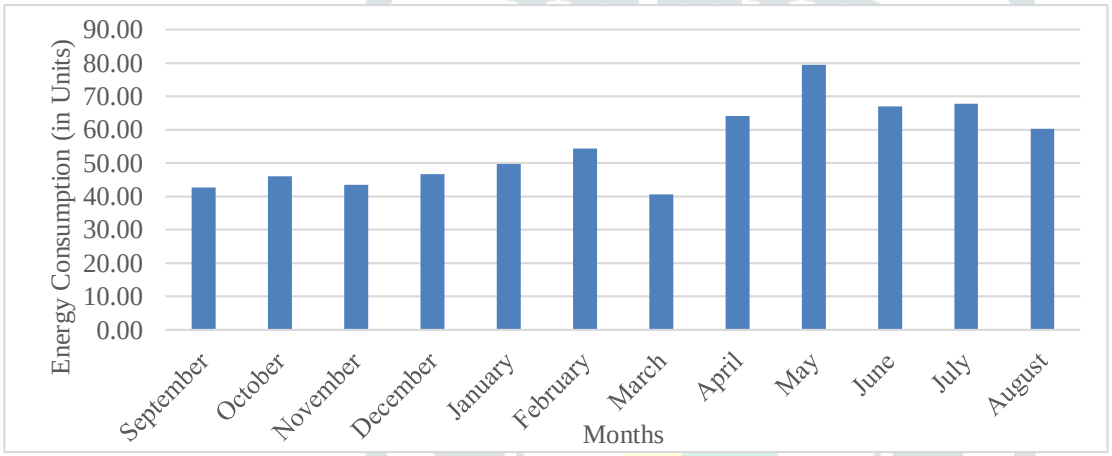

Fig. 8. Comparison of Electricity Consumption of Different Users

3.3. Variation in Month-Wise Average Electricity Consumption

The monthly average variation in electricity consumption was shown in figure 8. It was observed that there was a clear variation in electricity consumption throughout the year. The highest electricity consumption was found in the month of May. As May month is counted under summer month, in summer due to high temperatures the use of fans, ACs, water coolers, and refrigeration increases. And it affects overall electricity consumption. Also, the lowest electricity consumption was found in the month of December.

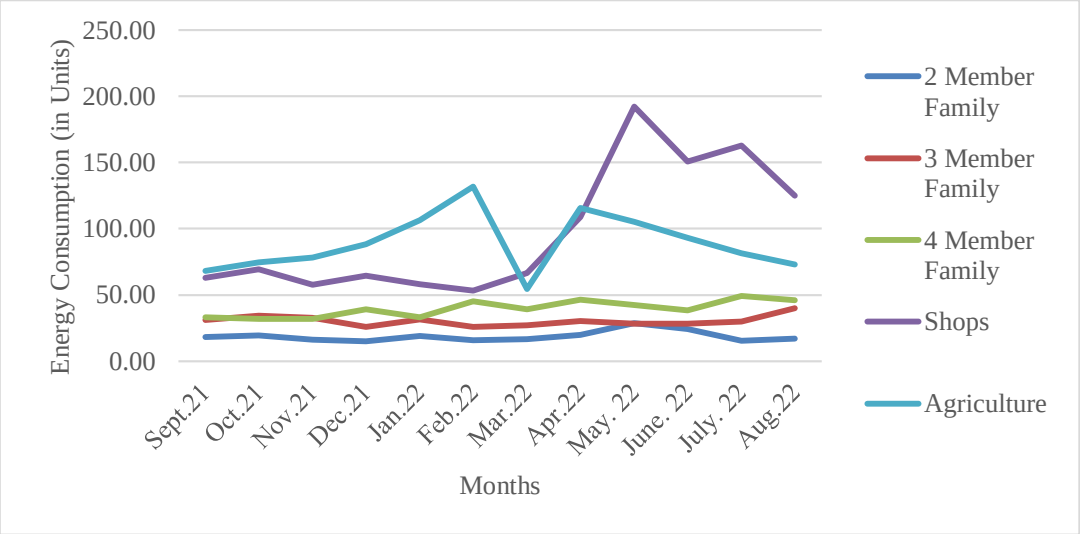

Fig. 9. Variation in Month-Wise Average Electricity Consumption

3.3. Design of Solar Panels

From this data, the average need for electricity per house is 26 Kwh. Considering 6 solar hours and an 85 % environmental factor, there is a need for a 0.15 kW solar array size with a 1.4 m2 area for solar cells. From these calculations, we found that there is a need for 1 solar panel assuming 300 watts of output per panel.

Table 2. Materials used for solar cell manufacturing with their efficiency and cost.

Materials	Efficiency (in %)	Cost/300-watt panel	Availability	Ratings as per study
GaAs	30	23625 INR	Low	4
Crystalline Silicon	22	13500 INR	Medium	7
CdTe	18	10350 INR	High/Easy	9

4. Conclusions

MEDA administers solar panel subsidies in Maharashtra. By providing financial support, this subsidy enables people to install solar panels. The subsidy information is as 30% of the standard cost is the amount of the state's subsidy and up to 10 kW of rooftop solar system capacity

With a growing family, there is an increase in electricity use. The highest electricity consumption was found in the month of May. The lowest electricity consumption was found in the month of December. Thin film -Cadmium telluride (CdTe) material was found to be the best and most efficient for manufacturing solar panels. Hence this prototype can be useful for a self-sustainable village model using solar energy.

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