The Role of Single End-Users and Producers on GHG Mitigation in Pakistan—A Case Study

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Abstract: End energy user is dependent on fossil fuel-based main-grid and contributes toward greenhouse gases (GHG) emissions. Changing its energy source will change the dynamics of the power plant, contribution towards GHG production. This case study aims to highlight the minute but positive role of a single end energy user, invisible to the main grid in GHG mitigations through photovoltaic energy source, selected among Pakistan’s top 10 most populous cities as per census 2017. Quetta is a selected city in Pakistan as the best fit location based on annual average daily solar radiations (AADSR) data retrieved from National Aeronautics and Space Administration (NASA) meteorological data. Helioscope software is used to select −15° tilt and 180° azimuthal angles, which further increased Quetta’s AADSR value from 5.54 kWh/m²/d to 5.93 kWh/m²/d. For research significance, a realistic approach is undertaken by proper selection of solar panel type based on Quetta’s annual average temperature, load categorization, user selection and inputs from a solar energy expert. Finally, initial cost, investment and GHG mitigation analysis are carried out in RETScreen Expert software, which validates the minute but the prominent role of a single, end energy user by mitigating 122 tons of CO₂ in 25-year project life span. Further, the proposed project favors end-user financially by recovering its $4501 initial cost in less than four years by effectively meeting its energy demand and saving $1195 per annum.

Keywords: GHG mitigation; end energy user; cost; CO₂

1. Introduction

The IPCC (Intergovernmental Panel on Climate Change) approach of life cycle assessment (LCA) analysis evaluates the scientific, socio-economic data for human-caused climate change, its potential impact and options for mitigations in 1988 [1,2]. Climate change is an environmental issue caused by greenhouse gases (GHGs) such as carbon dioxide (CO₂), methane, nitrous oxide, water vapor, etc., which traps the sun’s radiation in earth’s atmosphere causing global warming [3,4]. Global warming is a severe threat to human existence, endangering the quality of life [5]. The majority share of GHG across the globe is of energy industries; conventional power plants burning coal, oil and gas [6]. Developed countries like Group of Seven (G7) and Brazil, Russia, India, China, and South Africa (BRICS) contributed to 60% of global GHG emissions majorly through their energy industry alone in 2017 [7]. On the contrary, a developing country, Pakistan struggling from energy shortages since its birth, five gigawatts to seven gigawatts in 2017, is heavily dependent upon conventional power plants spread across the country to meet its energy demand [8,9]. With the world being in the context of global warming; climate change is implementing alternatives mostly green renewable energy resources [6].
Green renewable energy resources address the two major issues, firstly these replenishable energy resources in scenario of the world are facing depletion of fossil fuels issue, and secondly, in their lifetime they do not produce GHG in operation phase unlike conventional power plants, providing a solution to climate change issue.

Solar energy and green renewable energy are the best alternatives in meeting energy demand, while following the track paved in Paris Climate Accord. It serves as the reason for solar energy being the most explored renewable energy source, and literature has encouraged users and government to move toward a sustainable solar energy system [10]. A South Asian developing country, Pakistan, has been burdened by energy sector circular debts [11] while facing severe energy shortages or an energy-deprived country [8]. In the literature, several researchers commented on Pakistan’s energy approach along with her role in global GHG emissions since it is heavily relying on conventional power plants for her energy demands to keep her economy on track [9,12]. Pakistan’s generation in GWh for the year 2017–2018 is provided in Figure 1, reflecting its dependence on conventional energy resources. Pakistan’s major share of thermal energy is produced and imported by independent power producers (IPP) and K-Electric (KE). Pakistan’s thermal power plants include a gas turbine, steam turbine and combine-cycled power plants using natural resources such as coal, oil, bagasse, diesel and gas as its fuel [7,13]. Detail of Pakistan’s thermal power plant is available via [13].

![Energy Generation in GWh for FY 2017-18](image)

**Figure 1.** Pakistan’s power generation in GWh for fiscal year 2017–18.

On the contrary, and due to its dependence on conventional energy resources, Pakistan is the recipient of green renewable energy sources such as wind and solar because of its unique geographical location. Pakistan’s official resources, the Alternative Energy Development Board (AEDB), estimates the solar potential of Pakistan to be twenty-nine hundred [14]. Pakistan’s latitude and longitude coordinates support solar energy; ranging from five to seven kilowatt-hour per meter square average daily solar radiation, while the sun is out there for eight to ten hours a day and above in summer season. Pakistan receives solar irradiations for more than three hundred days a year [15,16].

However, electricity production through solar energy is highly limited to that specific location’s daily solar radiation, which is limited to unique geographical coordinates of that specific site [4,17]. Moreover, the literature suggests that the grid-connected solar photovoltaic (PV) systems are more feasible, reliable and economical than standalone systems [18]. Furthermore, to attract an investor for investment decisions, a detail techno-economic and environmental analysis are required [19]. Supporting the cause, RETScreen a user-friendly software developed by Canada is used to carry out detail analysis on different types of system such as power plants for decision making on solid grounds [17]. In the literature, multiple studies on green renewable energy resources are undertaken using RETScreen software to analyses feasibility, risk, sensitivity and GHG mitigation assessment across the globe. These analyses specifically target GHG mitigation analysis in lack of other solar software such as Solargis and Photovoltaic Geographical Information System (PVGIS). RETScreen tool
supports governments with respective study locations in order to allow for better decision making through multiple and detailed analyses. For instance, profitability and GHG mitigation potential analysis were undertaken by Nigeria’s 25 sites for a 100 MW PV plant, which suggests the best fit location and least fit location in both perspectives [4]. Ghana’s PV system potential and economic viability in 24 locations of the country for a 5 MW grid-connected PV system can be seen for profitable locations and their GHG mitigation potential [20]. The UAE’s Abu-Dhabi’s 10 MW PV system’s energy production, financial and GHG emissions mitigation potential analysis has been researched [21]. Saudi Arabia’s 10 MW grid-connected PV plant’s techno-environmental and economic analysis at 44 sites for an ideal location for PV plant installation have been identified [22]. Northern Cyprus 100 MW PV system economical and techno-environmental analysis for best fit location among five sites, selecting the best location on the basis of daily solar radiation are found in [10]. For instance, in Pakistan, Karachi has a huge potential of rooftop PV due to its millions of household population and locational solar potential [23]. This explains the household’s potential for GHG mitigation in Pakistan. Moreover, literature also covers hybrid green renewable energy system assessment on RETScreen for better investment decision making [24,25].

In the literature, specifically in Pakistan’s scenario, 185.97 Mt of CO$_2$ equivalent (45.91%) was emitted by the energy sector. The industrial process was responsible for about 21.85 Mt of CO$_2$ equivalent (5.39%) emissions, whereas 174.56 Mt of CO$_2$ equivalent (43.09%) emissions are caused by the agriculture sector. The land use and forestry accounted for 2.56% with 10.39 Mt of CO$_2$ equivalent, and the waste caused 12.27 Mt of CO$_2$ equivalent (3.03%) emissions in the atmosphere of Pakistan are found in [26]. In the energy sector, electricity and heat demand accounted for 31% (57.6507 Mt of CO$_2$ equivalent) of GHG emissions [26].

To mitigate the electricity sector’s 57.6507 Mt of CO$_2$ equivalent GHG emissions in Pakistan, literature has either focused on megawatt PV plants; 10 MW PV plant [27] or entire regions/provinces of Pakistan; Sindh [28], Punjab [29] and Balouchistan [30]. This study’s novelty lies in the aspect that the impact of single end energy user in GHG mitigation is somehow neglected/ignored. This, single end energy user is dependent upon fossil-fuel based national grid to meet its energy demand. The GHG mitigation impact is very minute by a single, end energy user, but in a PV system lifetime, it can avoid tons of CO$_2$ emission in the atmosphere.

In this case study, a grid-tied residential photovoltaic system analysis is carried out to understand the minute role of single, end energy user of the main grid in GHG mitigations. Firstly, Pakistan’s top ten most populated cities are analyzed based on average daily solar radiation data provided by National Aeronautics and Space Administration (NASA) meteorological data and ground sources to select the user with the highest impact or potential in GHG mitigation. Based on best location’s temperature, best fit type solar panels are considered, along with user categorization and load definition of best location, which is provided by a solar energy expert for the more realistic representation of the PV system. PV plant installation is optimized, i.e., tilt and azimuth angle through HelioScope software. Furthermore, and finally, the proposed PV system is analyzed for end energy user in terms of feasibility, i.e., cost and financial perspectives, and in terms of climatic GHG mitigation play through RETScreen Expert software.

2. Methodology

End energy user is solely dependent upon the main grid to meet its energy demands. Since the main grid is majorly conventional power plant-based system and involves GHG emissions, a single end energy user indirectly contributes towards GHG emissions by consuming primary grid energy. The single, end energy user role is very minute, but it can play a vital role in GHG emissions mitigation by shifting to the solar green renewable energy system. It will minimize the main grid’s peak load and stabilization of the grid by reducing the load while decreasing its dependence on conventional power plants. For this purpose, Pakistan’s top 10 most populated cities, as per Pakistan’s census 2017 [31] are
analyzed for the selection of a single, end energy user for detail analysis based on annual average daily solar radiation. The flow diagram is provided in Figure 2.

![Flow diagram of the proposed approach.](image)

2.1. Location Selection

Pakistan’s top ten populated cities are analyzed in terms of daily solar radiation to produce maximum energy through PV system and with its highest impact in GHG mitigations is selected first from Pakistan’s officially census 2017 [31]. Geographical data of each location, i.e., latitude, longitude, elevation, daily solar radiation, wind speed and air temperature, is taken from NASA Meteorological data provided by RETScreen Expert [17]. All sites are ranked in percentage with a single location which receives the highest annual average daily solar radiation, the parameter which affects most the output of PV system [4]. Data are shown in Table 1.

NASA provides data of every location at a specific site of a city like Karachi airport which is assumed for whole Karachi city. Moreover, NASA assumes the climatic condition of twin cities Rawalpindi and Islamabad as same. Therefore, this is a minute limitation of NASA geographical data provided by RETScreen Expert.

Quetta is selected as the best fit location for detail analysis on the single user energy end, since it receives the highest amount of annual average daily solar radiations; therefore it has the highest PV potential. Hence, Quetta’s end energy user has the highest impact in GHG mitigations because of high PV system yield. Monthly average daily solar radiation of Quetta is shown in Figure 3.
2.2. Selection of Solar Panels

Solar panels efficiency depends upon operating temperature [32] since the selected location is based on daily solar radiation so best match high-efficiency solar panels are required for that specific location. For this purpose, multiple solar panels were studied, for instance, monocrystalline solar panels, mono-perc, poly-crystalline solar panels and poly-perc etc. Based on energy expert, solar panels operating temperature range and percentage of efficiency drop with an increment of temperature (in °C) suggested monocrystalline solar panels are ideal for the specified location. Data of solar panel is provided in Table 2.

Table 2. Solar Panel Data.

| Model        | BLD-290W |
|--------------|----------|
| Normal Operating Cell Temperature; ambient temperature | 20 °C     |
| Temperature Coefficient of Pmax                        | −0.38%/°C |
| Temperature Coefficient of Voc                         | −0.36%/°C |
| Temperature Coefficient of Isc                         | 0.07%/°C  |

2.3. Load Categorization

Electrical load consuming energy to process it as per user demand varies with the size of the appliance. However, broadly load can be categorized in terms of its usage time; occasional load, seasonal load and continuous load. For instance, lights are used for illumination throughout the year and majority time of day. Further, a 1.5 horsepower (hp) motor is used to pump water from ground to water tank on the rooftop, so these are categorized as continuous load. Fans and Air Conditioners (AC) are seasonal loads heavily operating in the specific season but not throughout the year and accounts...
for majority of energy consumption. The last category is occasional load, which is operated throughout the year, but its operation time is very limited, for instance, a microwave oven operates throughout the day for maximum 10–15 min in an average household. Therefore, load categorization for the PV system is necessary. Data of load categorization is provided in Table 3. Continuous load and seasonal load (summer) are used for optimal sizing of the PV system.

| Load Type         | Load Rating (Watts) | Load Nature |
|-------------------|---------------------|-------------|
| Fan               | 75                  | Seasonal    |
| Light             | 12                  | Continuous  |
| Fridge            | 600/480             | Continuous  |
| LED TV            | 80                  | Continuous  |
| AC                | 1676                | Seasonal    |
| Washing Machine   | 1000                | Occasional  |
| Iron              | 2000                | Occasional  |
| 1.5 hp water pump | 1119                | Continuous  |
| Vacuum Cleaner    | 1400                | Continuous  |
| Microwave Oven    | 1200                | Occasional  |
| Electric Heater   | 1500                | Seasonal    |
| Miscellaneous     | 250                 | Continuous  |

2.4. User Selection

Quetta is a densely populated city of Pakistan [31], while energy consumption varies from user to user. Users based on energy consumption can be categorized to simplify the analysis. The average household connected load is estimated by reference to incorporate the city users to carry out the detail investigation. Estimated user load is provided in Table 4.

| Load                  | Quantity (Units Installed) |
|-----------------------|----------------------------|
| Fan                   | 6                          |
| Light                 | 12                         |
| Fridge                | 1                          |
| AC                    | 2                          |
| LED TV                | 1                          |
| Washing Machine       | 1                          |
| Iron                  | 1                          |
| Electric Heater       | 2                          |
| Microwave             | 1                          |

The continuous load is the primary need of the user. However, the seasonal load is heavily operated in seasons and summer season load (AC, fan, etc.) is higher compared to winter load (electric heater). In contrast, occasional load operation time is too low to be considered as the necessary load to be met through the PV system. Therefore, the occasional load can be met by the national grid since the considered system is grid-tied. Based on Table III, estimated considered load for the PV system is equivalent to 4876 watts.

2.5. Tilt and Azimuth Angle

Tilt angle is a measure of the angle between the solar panel and the horizontal plane. It plays an important role in increasing PV system output [33]. In the literature, a tilt angle is assumed as the latitude of that location or a fixed value. In this study, Helioscope [34], a solar energy design study, is used to estimate tilt and azimuthal angle for Quetta. Data are provided in Table 5.
Table 5. Photovoltaic (PV) Panels Placement through Helioscope.

| Parameter   | Angle |
|-------------|-------|
| Tilt angle  | −15°  |
| Azimuth angle | 180   |

PVGIS estimates 30° tilt angle for Quetta equivalent to its latitude. The impact of tilt angle for the proposed PV project in Quetta through RETScreen Expert software is shown in Table 6. Positive tilt angle means facing south, and a negative tilt angle means facing north.

Table 6. Impact of Angles on Daily Solar Radiation in Quetta Proposed by Helioscope.

| Month   | Daily Solar Radiation-Horizontal (kWh/m²/d) | Daily Solar Radiation −15° Tilt, 180° Azimuth (kWh/m²/d) | Daily Solar Radiation −30° Tilt (kWh/m²/d) |
|---------|---------------------------------------------|----------------------------------------------------------|--------------------------------------------|
| January | 3.42                                        | 4.24                                                     | 4.83                                       |
| February| 4.25                                        | 4.91                                                     | 5.31                                       |
| March   | 4.78                                        | 5.17                                                     | 5.30                                       |
| April   | 6.25                                        | 6.42                                                     | 6.27                                       |
| May     | 7.03                                        | 6.9                                                     | 6.46                                       |
| June    | 7.75                                        | 7.43                                                     | 6.80                                       |
| July    | 7.00                                        | 6.79                                                     | 6.29                                       |
| August  | 6.64                                        | 6.7                                                     | 6.42                                       |
| September| 6.42                                       | 6.88                                                    | 6.97                                       |
| October | 5.42                                        | 6.3                                                     | 6.83                                       |
| November| 4.11                                        | 5.11                                                    | 5.82                                       |
| December| 3.33                                        | 4.25                                                    | 4.93                                       |
| Annual  | 5.54                                        | 5.93                                                    | 6.02                                       |

Electricity generated/ exported to grid (RETScreen Software result) 10,989 kWh 11,951 kWh 11,925 kWh

Table 6 suggests, considering tilt angle equivalent to its latitude receives 6.02 kWh/m²/d amount of annual average daily solar radiation, higher suggested by Helioscope and without tilt. However, considering latitude as tilt angle yields higher monthly average daily solar radiation in the winter season, in which the sun is available for least hours. However, tilt and azimuth angle suggested by helioscope receive a higher amount of monthly average daily solar radiation in the summer season, in which sun shines for longer periods. Therefore, tilt and azimuth angle suggested by Helioscope is more appropriate for analysis. However, the annual result of both tilt angles suggested by PVGIS and Helioscope is almost identical.

2.6. PV System

PV system data for specified location Quetta for single, end energy user after its load categorization is suggested by energy expert of the solar industry to be minimum 6500 Watts to meet the energy demand of the user. The load varies all day, and produced energy is first used to meet user demands, and in the case of unused/surplus energy, units (kWh) are credited to the main grid through net metering in order to keep the system’s efficiency to the highest level and for later use. Inverter and PV data are shown in Tables 7 and 8. To have the higher efficiency of PV system, PV panels of 290 watts each are considered, which increases our system PV value to 6670 W from 6500 W.

Table 7. Inverter Data.

| Model                              | Inverex—Atom-7 KW |
|------------------------------------|-------------------|
| Max. Active Power                  | 7.7 kW            |
| Frequency                          | 50/60 Hz          |
| Output power factor                | >0.99             |
| Grid current total harmonics distortion | <3%              |
| Max efficiency                     | 98.3%             |
| MPPT efficiency                    | >99%              |
| Lifetime                           | >20 years         |
Table 8. PV Panels Data.

| Parameter                    | Value       |
|------------------------------|-------------|
| Maximum Power (Pmax)         | 290 Wp      |
| Voltage at Max Power         | 32.44 V     |
| Current at Max Power         | 8.94 A      |
| Open Circuit Voltage         | 39.11 V     |
| Short Circuit Current        | 9.54 A      |
| Panel efficiency             | 17.82%      |
| Cell type                    | Mono crystalline |

3. Results

3.1. Initial Cost

The initial cost is an analysis carried out for the end-user to ensure prices lies in his/her purchasing power. Capital cost analysis is required for the user in order to match it with his purchasing power. The initial cost of the proposed system as per user load, location and purchasing power, is given in Table 9. These costs are estimated after discussing with solar energy experts and firms offering solar solutions in Pakistan.

Table 9. Initial Cost of the Proposed PV System.

| Initial Cost                              | Initial Cost | Percentage |
|-------------------------------------------|--------------|------------|
| Feasibility Study                         | $49          | 1.1%       |
| Engineering                               | $1169        | 26%        |
| Power System                              | $1978        | 44%        |
| Balance of System and Miscellaneous       | $1305        | 29%        |
| Total                                     | $4501 USD    | 100%       |

The feasibility study captures the cost of site investigation, resource assessment, environmental assessment, and detail cost estimate and reports preparation. The engineering section includes mechanical design for solar panels, the electrical design which further subcategorized into fuses, surge protection devices, the four pole AC breaker, the DC wire, and the four core AC cable and net meter. The civil design includes a DC grounding installation. Furthermore, and finally, it includes the cost of tender and contract. Power system refers to the cost of PV panels only, and the balance of system and miscellaneous includes the cost of inverter and transportation costs. Cost of a single dollar is equivalent to 168.58 Pkr for this analysis.

3.2. Investment Analysis

The Government of Pakistan offers income tax and premium tariff exemption to support renewable projects [35]; therefore, the investment study of the proposed PV system includes no income tax and premium tariff. Moreover, electricity per unit cost for residential loads consuming more than 300 kWh and less than 1000 kWh is 0.073 $/kWh [36]. The electricity escalation rate is considered to be 6% per annum following its preceding electricity growth pattern in [27]. This analysis is carried out at by the end energy user, parameters like debt ratio, debt years etc. are considered zero since such small projects are often the initiative of end energy users on their own expenses. Some of the financial values are assumed by the RETScreen software and are used as it is, while the rest of the parameters are taken from referenced resources. Financial parameters, along with their values, are shown in Table 10. Operation and maintenance cost is low since project efficiency is majorly affected by the location’s dust. operation and maintenance (O&M) cost for a fixed PV system is estimated at $11.86 per year. These values were carefully chosen after communication with a solar energy expert.

Project total cost is $4501, excluding O&M costs. Electricity generated is 11,951 kWh per annum, which is equivalent to spending $1195 per annum. The annual cumulative net present cost and annual
income/cost of the project are illustrated in Figures 4 and 5. This project is financially viable as the initial cost is recovered in less than four years and the end energy users start earning in the following years.

### Table 10. Financial values for the Proposed PV system.

| Electricity per Unit Cost | $0.073 $/kWh [36] |
|---------------------------|-------------------|
| Electricity escalation rate per annum | 6% [27] |
| Debt ratio | Zero |
| Inflation rate | 6.5% [37] |
| Discount rate | 9% [27] |
| Project life | 25 years |

![Figure 4. Cumulative cash flow of the PV project at Quetta.](image)

![Figure 5. Annual income/cost of the PV project at Quetta.](image)

The proposed project is financially attractive since PV project generates 11,951 kWh per annum with O&M at $11.86 per annum. The project in its lifetime produces 298,775 kWh (assuming the same efficiency of PV, for simplicity) with $4797.5 cost including initial and O & M cost of a 25-year project life. A single kWh produce by solar energy is 0.0161 $/kWh while a single kWh from grid costs $0.073.

### 3.3. GHG Emission Analysis

Burning of gases involves a number of gas (CO$_2$, H$_2$O, NOx, etc.) emissions. RETScreen provides an innovative solution by providing an equivalent annual amount of CO$_2$ to total emissions. It is processed by translating emission gases into CO$_2$ based on their global warming potential [3]. However, in this project, electricity exported to the grid is nearly 12 MWh per annum. The GHG emission factor, excluding transmission and distribution energy losses, is equivalent to 409 kg CO$_2$ per MWh if all
fuels types such as coal, gas, etc. are used to generate the equivalent electricity [17]. Transmission and distribution losses are neglected since the project is mounted directly on end energy user with priority, meeting user load first. Thus, per annum, this project reduces 4.9 tons of CO$_2$ if 12 MWh of energy is supplied by the main grid, which is based on conventional energy resources.

Since Pakistan relies on coal as power plant fuel and considering coal as fuel, the proposed system mitigates 2.459 tons of CO$_2$ in a single year through the PV system mounted on a single, end energy user of Quetta city.

For better reference, 4.9 tons of CO$_2$ is equivalent to 2100.8 L of hoard gasoline, 1.7 tons of waste recycled, 11.4 barrels of crude oil not consumed, and 1.1 acres of a forest absorbing the same carbon. The project in its lifetime reduces 122 tons of CO$_2$.

3.4. Proposed Project GHG Mitigation Effectiveness

The literature, in the scenario of Pakistan, suggests a 20 kW diesel generator produces the electricity of 4 kWh/L [28] which was used as a scale to calculate the consumption of liters in the case of a diesel engine for Sindh, Punjab and Baluchistan—provinces of Pakistan [28–30]. Using the same approach, the proposed project in case of diesel oil-dependent consumes 2987.75 L/year and in its 25 year lifetime, consumes 74,693.75 L of oil to generate 298,775 kWh of energy.

As per the World Bank, Pakistan’s per capita energy consumption was 447.50 kWh in 2014 [38]. Quetta’s population is 1,001,295 [31]. If each head needs 447.50 kWh, Quetta residents consumes 112,009,809,375 L/year. The proposed project saves 74,693.75 L in case of 6670-W PV project’s 25 years and can save up to one trillion liters in a year by switching to the PV system. Quetta’s switching to PV system as an energy source can mitigate a huge level of CO$_2$ per annum, tackling global warming at end energy user level, invisible to the main grid but playing a pivotal role.

3.5. Study Significance

Across the globe, households, and end energy users have the least share of GHG emissions. Like in Pakistan, 89% of GHG emissions (360 Mt of CO$_2$ equivalent) are contributed by industry and agriculture sector. However, a single end energy user in a populous country like Pakistan can play a minute but positive role in GHG emissions mitigation through the use of a PV system. The 6670 W PV generates 11,951 kWh per annum, and a single head needs 447.50 kWh [38] in a year. The proposed system can effectively meet 26.71 single users energy demand, while avoiding 4.9 tons of CO$_2$ equivalent. Specifically, in terms of Quetta’s population, Quetta has potential to mitigate 183,689.46 tons of CO$_2$ equivalent GHG emissions through PV system considering its 1,001,295 heads [31]. This small scale project indirectly reduces GHG emissions by reducing the load on fossil fuel-based power system and has positive cash flow in less than five years.

4. Conclusions

End energy users of Pakistan, because of their unique geographical location, can play a minute but positive role against GHG emissions. A single user, depending upon his average energy demand throughout the year can invest into small scale PV system without any financial conditions required for mega projects like debt term, debt years, etc. A user can meet its energy demand and credit the surplus kWh into the main grid through net metering. Through this approach, a user mitigates GHG emissions by not consuming energy fed from a fossil fuel-based national grid, recovers initial cost in four years and has positive cash flows (in household savings) in following years. They even reduce the dependence of Pakistan’s national grid on fossil fueled-based power system, and this helps in peak shaving and grid stabilization of an energy deficit country, such as Pakistan.

Future studies should include the role of energy user shift to electric vehicles and charging it from a PV system as well as meeting its home energy demand at the same time, playing a role in mitigating GHG emissions of the energy and transport sector at a grass roots level.
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