# Feasibility study on Grid connected PV system in Nepal

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**Abstract**
The climatic conditions of Nepal are ideal for solar energy technology. Indeed, stand alone PV plants are used in remote areas, grid connected systems however are not yet well enough considered.
The power supply system is suffering from lack of production forcing the distributor to practice regular load shedding. Therefore, using the energy production potential of grid connected PV plants could substantially contribute in making the national power supply system more diversified and independent, and more ecologically and economically sustainable.
The aim of the project (October 2008 – December 2009) was to conduct a feasibility study on PV grid connected plants in the Kathmandu Valley, Nepal, and the consequent development and delivery of an educational program.
Nepal benefits from extremely favorable climatic conditions for the use of PV technology with grid connected plants. A south oriented 30° tilted photovoltaic installation can produce 1700 kWh/kWp/Year. The same installation can produce 2300kWh/kWp/Year if installed on a two-axes sun tracker. The initial investment is high but is paid off by a high production and by a cost of 19.6NRs/kWh of the final energy that is by far less than the one produced by the systems at use in households during load shedding periods (inverter-batteries: 54.0NRs/kWh; genset: 55.4 NRs/kWh), or by thermal power plant (ca. 30NRs/kWh).
PV energy can contribute to the reduction at all times of the year of the country’s energy production deficit.

*Keywords*: Photovoltaic, Grid Connected System

## 1. INTRODUCTION

Even disposing of an extraordinary potential for hydropower production, lack of investments, political instability and increase of energy demand have driven the country in a severe energy crisis, with as much as sixteen hours of load shedding a day during springtime 2009. The energy crisis will certainly find solutions and ways out through the diversification of electricity sources in order to increase the production capacity at short and long term, with –hopefully– careful consideration of global sustainability criteria. Grid-connected PV technology could be part of the “package” of the future electricity supply scheme of Nepal but the conditions and criteria to make it applicable in the given context are manifold and influenced by various dimensions such as technical, institutional and economic. Though the investigation for alternative energy sources development is a central and recognized issue in the energy sector in Nepal, the present study is the first one to consider specifically the feasibility of PV grid connection throughout the country. The reference context considered in this study is the Kathmandu Valley.

SUPSI has conducted this feasibility study and training program in close collaboration with the NSES (Nepalese Solar Energy Society) and the Center for Energy Studies CES/TU - Institute of Engineering - Tribhuvan University, the NGO RIDS-Nepal and the Kathmandu University.

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## 2. METHODOLOGY

The research for information and necessary data for assessing the feasibility has been organised at different levels: climatic conditions, actual PV market conditions, institutional setup, national electricity grid conditions and characteristics, economy of the energy sector in Nepal, main stakeholders, domestic users and industrial and service sectors point of view.

All data and information has been then analyzed in order to establish to what extend PV grid connected technology is feasible in Nepal, considering three main criteria: technical, economic and institutional feasibility.

A survey on a selected group of potential domestic users has been carried out. In order to focus on a category of possible future users of PV grid connected technology, mainly middle-upper class families within the Kathmandu agglomeration have been interviewed. Three hundred and nineteen households have provided valid feedbacks to the structured interviews.

In order to draw a representative point of view from potential users of PV grid connected technology among the industry and service sector in Nepal, a survey was conducted through structured interviews to a selected group of fifty-four companies.

## 3. FINDINGS

### 3.1 Climatic condition

With about 300 days of sunshine per year in most parts of the country, an average of eight light hours per day and being situated on the ideal 30° North "solar belt", Nepal presents very good conditions for the use of solar power. Solar PV modules installed at an angle of 30° South can intercept a daily average of 4.8 to 6.0 [kWh/m2] of solar energy in most locations throughout the country [1].

The compared climatic data comes from various sources: 1) NASA Surface meteorology and Solar Energy Data (considered as the most reliable ones); 2) Meteosat, SWERA project, DLR final report; 3)Measured data (by RIDS-Nepal); 4) Meteonorm.

The yearly evolution of solar irradiation in the Kathmandu valley, Nepal, is, unlike for European countries, easily predictable. Furthermore, 'climatic risks' such as hail, strong winds, tornados etc. do not occur.

The difference between NASA data and data measured by RIDS-Nepal in 2004-2005 is only of 3.3 %. In the case of Meteonorm data, this difference is only of 2 %. Meteonorm often gives lower values than the average. This means that simulations with default values with software such as PVsyst tend to be rather conservative, and give prudent results for the final yield of the customer's system. For an especially conservative approach, NASA data should be employed. For the present study, Meteronorm data was used, with a value of horizontal yearly irradiation of 1950 [kWh/m2/year], plus 70% compared to southern Germany.

The optimal titled angel for a maximal yearly irradiation derives from the transposition factor. The highest yearly irradiation value is obtained with a south oriented and 30° tilted angle flat surface. Also, the temperature has a relevant influence on PV modules behavior (an increase of temperature decreases the productivity with a factor of -0.4 [%/K] (valid only for crystalline cells). In Kathmandu, the solar path diagram shows a minimal sun elevation of 35° in winter and a maximal one of 90° in summer. But, because of the major presence of clouds and highest temperatures, summer is the season producing the smallest amount of PV energy. An increased tilt of the modules (compared to 30°) will globally add to the productivity over the year. With a 30° tilted angle, a module receives a global irradiation of 2'224 [kWh/m²/year] that corresponds to an increase of 12% compare to a horizontal surface.

Two-axis global monthly solar irradiation is 2940 [kWh/m2], that corresponds to an increase of 33.6% compared with the irradiation on a horizontal surface and an increase of 24 % if compared to a fix 30° tilted surface, and plus 130% compared to southern Germany.

For this study, only the urban areas of Kathmandu valley were considered, it was thus not necessary to calculate the horizon for assessing the hill generated shadows.

### 3.2 Energy production of a PV grid connected power plant

Favorable climatic conditions allow a high annual and easily predictable production.

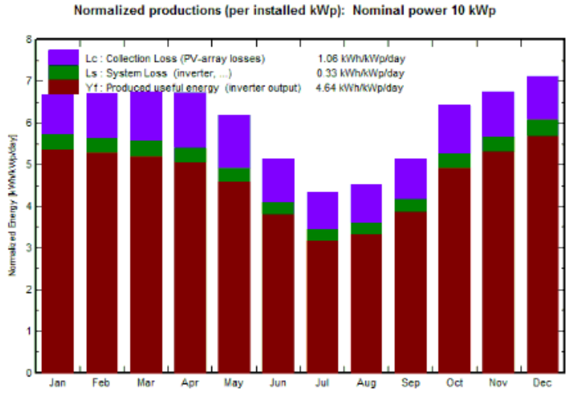


Figure 1: Normalised energy productions

An on-grid photovoltaic installation, mounted on a south oriented and 30° tilted fix structure, would produce 1700kWh/kWp/year. That is, an installation with 10kWp nominal power would produce 17MWh per year.

The same photovoltaic installation mounted on a two-axe sun tracker, could produce 23MWh/year.

If the two-axe sun tracker mounted installation had 1MWp nominal power, it would produce 2300MWh/year.

### 3.3 PV market condition

In Nepal, there are 59 companies selling photovoltaic modules, but only 26 are approved by the AEPC (Alternative Energy Promotion Center) and therefore have right to benefit from Rural area subsidies. The survey carried out for this study was on 23 out of 26 companies in Kathmandu approved by the AEPC.

The total amount of last year's photovoltaic module sales was of 44'245 units. 220 module types by 11 manufacturers (Kyocera, Solarland, Sharp, Kaneka, Solarworld, Suntechnics, Moserbaer, TATA BP, Isofoton, Primier Solar, Mitsubishi) have been pointed out.

The average power of these modules was of 49Wp, but the average power sold was of ca. 30W. The therefore estimated installed power in Nepal in 2008 amounts to ca. 1.3 MW.

The average cost per watt at the time of the survey (April 2009) was of 351 NRs/W (3.25 €/Wp) and in November 2009 was of 2.7€/Wp.

The market of the inverters for the connection to the grid is still inexistent. The battery charger (from grid), battery and classic DC/AC (12Vdc/230Vac) inverter markets however, appear successful. The standard cost for stand-alone inverters amounts to ca. 20NRs/VA.

Globally, 7MW (of which 1.3MW only in the fiscal year 2008-2009) have been installed in Nepal. At present, there are ca. 200'000 installed SHS in Nepal.

### 3.4 Domestic users' point of view

A survey on a selected group of 390 domestic users was carried out. In order to focus on a category of possible future users of PV grid connected technology, mainly middle-upper class families within the Kathmandu agglomeration (Including Lalitpur) have been interviewed.

More than half (54.5%) of the owners used "Inverter-Battery Systems" which consist in charging batteries from the grid when this is functioning. Due to the drastic increase of load shedding periods, this system has become very popular in Kathmandu since it is relatively affordable (for this category of the society) and easy to install and run. However, considering the losses of such a system, it's use at larger scales highly contributes to worsen the problem of load shedding. About one third (30.1%) of the households just bears the inconvenient of load shedding without using any alternative source of electricity. This important percentage can be interpreted as a serious lack of appropriate solutions. About ten percent (9.7%) make use of solar PV-battery systems. However, a large number of these are of small size and are mainly used for emergency lighting only. Only few households use diesel (4.1%) or petrol and LPG generators. This is probably due to the constant diesel supply crisis.

About three quarters (74.0%) of the owners would agree to pay 10 [NPR/kWh] for a reliable power supply 24 hours / 7 days. This represents an over cost of 37% compared to the current total average electricity cost, but probably the same cost for this categories of family. One fifth (20.1%) can afford to pay 20 [NPR/kWh], about three percent would pay even 30 [NPR/kWh] and very few would be ready to pay up to 50 [NPR/kWh].

Looking at the type of electric appliances used by these households, it can be said that, for this particular group of society, the domestic economies have become highly electrified and a good numbers of activities are nowadays depending on electricity.

Most of the available roof surfaces for PV are of ca. 25 $m^2$. About five percent present available surfaces of 50 to 100 $m^2$.

In the opinion of more than ninety percent of the families, the main disturbance concerns education and study activities. This is explained by the non availability of light in the evening. The second most important disturbance (56.1%) concerns water supply. In fact, many households have their own well from which they daily pump the water to fill tanks placed on top of their roofs. Long interruptions of power supply can result in incomplete filling and therefore lack of water for the household. For more than thirty percent, the diminution of work capacity and income is also a serious issue that is mainly to relate with the difficulties in running computers, other electrical equipments and light.

### 3.5 Industrial and service sector's point of view

In order to draw a representative point of view from potential users of PV grid connected technology among the industry and service sector in Nepal, a survey has been conducted through structured interviews to a selected group of companies (54).

Various means of electricity production by companies during load shedding periods have been observed. The most popular options are diesel run generators (45%) and inverter-battery systems (38%). The common use of diesel run generators can be accounted to low price of diesel and the use of inverter-battery systems can be accounted to low maintenance costs and easy availability. Solar PV-battery system is only moderately used (5%), probably because of the relatively high investment cost. LPG and kerosene run generators (2%, respectively 1%) are only marginally used because they are more expensive to run compared to diesel generators. The industries with small scale production and lesser capital were observed to bear the inconvenience and wait for better times. This means that some have to temporarily close their activity.

Most of the industries (62%) seemed ready to pay up to 40 [NPR/kWh] to get reliable power supply for 24/7. Others (28%) complained about the rate and said that they could adjust at max around 20 [NPR/kWh] as they are getting electricity for 7.30 [NPR/kWh] from the grid itself. Eight percent of them (mainly software developers and a bank) declare to be ready to pay 50 [NPR/kWh] and 2% (consulting service) even 60 [NPR/kWh]. These results are presented in the graph below.

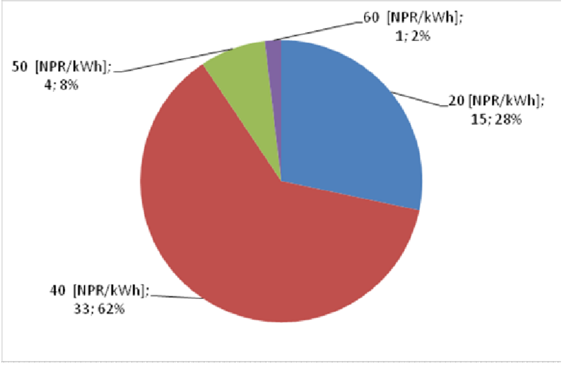


Figure 2: Willingness to pay for 24/7 power supply, for the industrial and services sector.

In urban areas, PV systems are generally mounted and fixed on the roofs. This is the reason for which it is very important to consider the issue of property of a PV plant possibly separately to the building's property. It appears that a large majority of the industries (around 70%) are installed in rented buildings and most of those have access to the space available on the roof and the ground of the building.

While the ground spaces were used for parking and other uses, the roofs were generally free, except for the installation of solar water heaters or water tanks. The average roof surface is about 100 [m2] and varies from 20 to 500 [m2]. The average surface that would be available for the installation of a PV plant is about 35 [m2] and varies from 5 to 100 [m2]. Generally, the industries were ready to provide around 20% - 65% of the free space on roofs to lease for PV module installation.

### 3.6 Analysis and comparison

The comparison between different productions and different production costs was carried out on technologies that can at present be found on the market (SHS, inverter with 600Ah of batteries, inverter with only 100Ah of batteries, petro genset of low quality and petrol genset of high quality), and with an on-grid photovoltaic installation (with or without back-up system).

For the comparison, general initial conditions were established:

- Daily consumption of the household: 5kWh/day.
- Constant load during the day.
- Avg. daily load shedding during the year: 7 hr.
- Cash payment of the investment.
- Grid Energy cost per unit: 9.9 NPR/kWh.
- VAT included (PV modules: 2.5%; others: 13%)

The impact on the grid of the different used and analyzed technologies can be observed in figure 3.

In yellow the energy produced by the different technologies is represented, in green it is possible to observe the energy fed into the grid. For both grid connected PV systems the whole produced energy is sent into the grid.

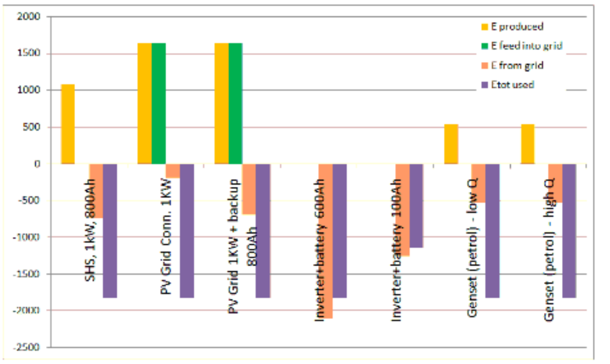


Figure 3: yearly energy [kWh/year] produced by the system, injected in to the grid, consumed from the grid and total energy used by the system.

On the negative axe of figure 3, the pink bar represents the difference between the energy sent into the grid and the energy taken from the grid. Photovoltaic grid-connected systems are the only technologies sustaining the grid. On the contrary, inverter plus battery systems are the only ones that worsen the grid condition by consuming more than the total used energy. This is due to the fact that they do not produce energy but need energy to compensate the losses in the backup system. Also, if the battery is too small, the available energy for sustaining the family household needs and lifestyle will decrease.

In the case of solar home system (SHS), a fix amount equal to 3kWh/day of energy taken from the SHS was considered. The remaining consumption is taken from the grid. In the case of genset, the system has no interaction with the grid, it produces only the energy needed during the load shedding.

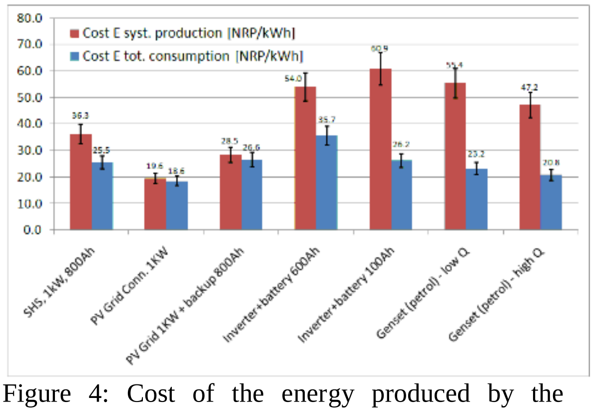


Figure 4: Cost of the energy produced by the systems, and cost of the energy used by the household (Esystem + Egrid).

Figure 4 shows, in red, the cost of the energy produced by the system, and in blue, the cost of the total energy consumed by the household.

It is clearly visible that grid connected PV system represents the most competitive option for energy production.

In the case of non solar systems, the total cost of consumed energy is less, because of the consumed 5kWh/d, only 1.46 kWh come from the system while the remaining 3.54 kWh are drawn from the grid at a reduced cost (9.9 NRs/kWh).

The common understanding that PV systems are expensive is due to the high initial investment cost. But in terms of energy costs, PV systems are very economic when compared to other alternatives because of the long lifespan of the technology (>25 years).

Even though inverter-battery systems present low investment cost, they have very high energy production costs because of their relatively short lifespan and their low efficiency. This is also true for the genset systems, which have a short lifespan and high running costs due to fuel.

In comparison, generation cost of central power plants are, for hydro, about 2 NRP/kWh (Kulekhani I: 1.90 NRP/kWh; Devighat: 1.47 NRs/kWh) and, for thermal plants, about 30 NRs/kWh (Hetauda Diesel: 31.50 NRs/kWh; Duhabi Multifuel: 29.40 NRs/kWh.

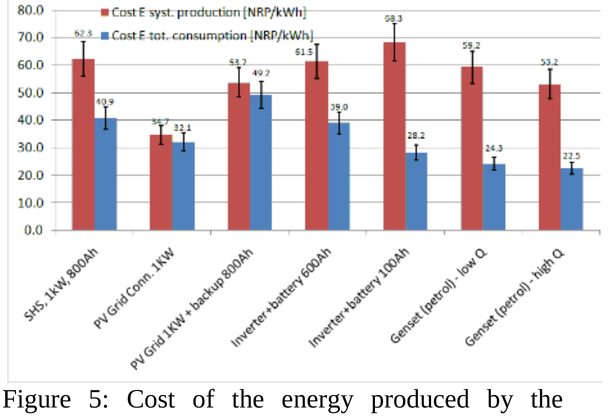


Figure 5: Cost of the energy produced by the systems, and cost of the energy used by the household (Esystem + Egrid), with investment: 50% cash, 50% loan at 9%.

Figure 5 refers to the costs considering an investment with 50% in cash and 50% with a facilitating rate (9%) bank loan.

In spite of unfavorable rates for an installation at high initial investment, the energy produced by a PV installation is always competitive. If the period of load shedding (at present of 7h/d) should increase, as officially expected, the cost of total used energy would become even more unfavorable for non solar technologies.

## 4. CONCLUSIONS

The power supply system in Nepal is suffering from lack of production forcing the distributor to practice regular load shedding. The building of new hydro electrical plants (the main potentiality in Nepal) requires important amounts of time and investments. The solar potential of the country is huge, particularly in the Kathmandu valley. The building of on-grid PV solar plants can be extremely fast (see German example: 800MW in one year) and could contribute to the diversification, independence and ecological and economic sustainability of the national power supply system. Their assembling could also provide work opportunities for the local inhabitants and the technology is appropriate both for small and bigger installations for the flexibility and modularity of its components.

Photovoltaic grid-connected systems are the only technology that can sustain the grid. On the opposite, inverter plus battery systems are the ones that worsen the grid's condition by consuming more than the total used energy. This because they don't produce energy and need additional energy to compensate the losses in the backup systems.

The production costs of on-grid photovoltaic installation produced energy (19.6 NRS/kWh) is lesser if compared to other stand-alone solar installations (36.3NRs/kWh), and even worse in comparison to the at present used installations during load shedding periods (Inverter+600Ah batteries: 54.0 NRs/kWh; genset: 55.4 NRs/kWh).

The general constant decrease of PV module and PV component prices along with a long life span and low and simple maintenance needs, will allow to get closer to grid parity.

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## REFERENCES

[1] Zahnd, A., McKay, K., & Komp, R. (2006). Renewable Energy Village Power systems for remote and Impoverished Himalayan Villages in Nepal. *International Conference on Renewable Energy for Developing Countries.*