University of Applied Sciences and Arts of Southern Switzerland
Department for Environment Constructions and Design
World Habitat Research Centre

SUPSI

Development of PV grid-connected plants in Nepal

A feasibility study and training programme co-financed by REPIC

TECHNICAL REPORT

VERSION 1.0

Lugano, Kathmandu, 21 June 2010

SUPSI-ISAAC
University of Applied Sciences of Southern Switzerland, Institute for Applied Sustainability to the Built Environment

CES-TU / NSES
Centre for Energy Studies, Tribhuvan University / Nepal Solar Energy Society

KU / RIDS-Nepal
Kathmandu University / Rural Integrated Development Service Nepal

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Acronyms

AEPC	Alternative Energy Promotion Centre, www.aepcnepal.org
BIPV	Building Integrated Photovoltaic (system, plant)
CDM	Clean Development Mechanism
CEDB	Clean Energy Development Bank
CES	Centre for Energy Studies (TU), www.ioe.edu.np/bodies/ces
CIA	Central Intelligence Agency
CHF	Swiss francs
DANIDA	Danish International Development Agency
DHM	Department of Hydrology and Meteorology
D&T	Developing and Transition (Country)
DSR	Dynamic Source Routing
CIA	Central Intelligence Agency
MG	Department of Mining and Geology
ETFC	Electricity Tariff Fixation Commission
FNCCI	Federation of Nepalese Chamber of Commerce and Industry
GDP	Gross Domestic Product
GoN	Government of Nepal
HAN	Hotel Association of Nepal
HDI	Human Development Index, www.hdr.undp.org
HH	Household
IEA	International Energy Agency
IEC	International Electrotechnical Commission
INPS	Integrated Nepal Power System
IPP	Independent Power Producers
ISAAC	Institute for Applied Sustainability to the Built Environment, www.isaac.supsi.ch
IT	Information Technology
KU	Kathmandu University
LABSOLAR	Laborationo de Energie Solar, Florianópolis, Brazil
LPG	Liquefied petroleum gas
MoAC	Ministry of Agriculture and Cooperatives
MoE	Ministry of Energy (MoWR until June 2009)
MoENV	Ministry of Environment
MoEST	Ministry of Environment, Science and Technology, www.moest.gov.np
MoFSC	Ministry of Forestry and Soil Conservation
MoIn	Ministry of Industry
MoIr	Ministry of Irrigation
MoST	Ministry of Science and Technology
MoTS	Ministry of Trade and Suppliers
MoWR	Ministry of Water Resources (MoE since June 2009)
MPPT	Maximum Point Power Tracking
NCC	Nepal Chamber of Commerce
NDC	National Development Council
NEA	Nepal Electricity Authority, www.nea.org.np
NEAGC	NEA Grid Code
NEPQA	Nepal Photovoltaic Quality Assurance
NGO	Non Governmental Organisation
NOCT	Nominal Operating Cell Temperature
NIPQA	Nepal Interim PV Quality Assurance
NPC	National Planning Commission, www.npc.gov.np
NPR	Nepalese Rupees (August 2009: 1 CHF ≈ 70 NRs)
NREL	National Renewable Energy Loboratory (USA)
NSES	Nepal Solar Energy Society
NWRDC	National Water Resources Development Council
PEC	Indo Nepal Power Exchange Committee
PPA	Power Purchase Agreement
PV	Photovoltaic
PVPS	Photovoltaic Power Systems Programme, www.iea-pvps.org
REPIC	Renewable Energy Promotion in International Co-operation, www.repic.ch
RETS	Renewable Energy Test Station, www.retsnepal.org
RIDS	Rural Integrated Development Service, www.rids-nepal.org

SEMAN	Solar Electric Manufacturers' Association Nepal
SHS	Solar Home System (PV) with minimum capacity of 10 Wp
SSHS	Small Solar Home System (PV) with capacity from 2.5 to 10 Wp
SDC	Swiss Development & Cooperation
STC	Standard Test Conditions
SUPSI	University of Applied Sciences of Southern Switzerland
THD	Total Harmonic Distortions
TISO	Ticino Solare
TU	Tribhuvan University
UKM	University Kabangsaan Malaysia
UNDP	United Nations Development Programme
UNITEN	University Tenaga National, Malaysia
UPS	Uninterruptible Power Supply
USD	US Dollars
VAT	Value Added Tax
VDC	Village Development Committee
Voc	Open circuit voltage
WASP	Wien Automatic System Planning
WEC	Water and Energy Commission
WECS	Water and Energy Commission Secretariat
Wp	Watt pic (power)

1 Summary

This project was co-funded by REPIC and SUPSI. It was achieved thanks to the close collaboration of SUPSI and two Nepalese partner teams: the CES of the Tribhuvan University together with NSES, and Kathmandu University alongside RIDS-Nepal. The project was implemented between October 2008 and June 2010.

So far, PV technology has been applied exclusively in standalone plants in Nepal, mainly in remote areas of the country. Despite for its huge hydro power production potential, Nepal is presently facing a dramatic energy crisis and a severe lack in electricity production capacity. Solutions and ways out of the energy crisis will certainly be found by diversifying the electricity sources so as to increase the production capacity in the short and the long term. Grid-connected PV technology could be part of the “package” of Nepal’s future electricity supply scheme, but the conditions and criteria to make it applicable in the given context are manifold and influenced by technical, institutional and economic aspects. These aspects have been analysed in the present study to assess its feasibility. Though the investigation for the development of alternative energy sources is a fundamental and acknowledged issue in the energy sector in Nepal, the present study is the first to look specifically at the feasibility of grid-connected PV in the country. The reference context considered in this study is the Kathmandu Valley. A training programme has been conducted simultaneously to the feasibility study, and students from TU and KU have been directly involved in the project’s activities.

The feasibility of grid-connected technology in Nepal has been analyzed considering the following three main criteria:

1. Technical feasibility
2. Economic feasibility
3. Institutional feasibility

The world PV market has grown at an extremely fast pace during the last years, and it is still progressing drastically. The vast majority of PV applications in the world are grid-connected, but this in fact is typical only in highly industrialized countries. In countries like China and India, only a marginal amount of the PV power installed so far is grid-connected. However, PV grid connection has been considered in many of developing countries, and various experiments and studies have demonstrated interesting potentials.

The climatic conditions of Nepal are extremely favourable for the use of solar energy systems in comparison with central European conditions (74% more solar energy received on the module’s surface in Kathmandu than in Munich) (see chapter 4.1).

The current Nepalese PV modules’ market is still very marginal (1.4 MW in 2008), and limited to standalone systems with mainly 36 cells modules. Because of the lack of systematic control, and because of the fact that the productivity of standalone systems cannot be monitored, the average quality of the modules is not always good. In November 2009, the average per-watt cost of PV modules in Nepal was about 2.7 €/Wp whereas the trend price in China in January 2010 was about 1.70 €/Wp. World module production is nowadays mostly dedicated to the realization of grid-connected systems. Module typologies with 36 or multiples of 36 cells are no longer necessary in a grid-connected installation. Most producers provide 60 cells modules. Differences in cost between the world and the Nepalese markets are due to the limitation of the latter to SHS and to small power (see chapter 4.2.1).
Inverters for PV grid connection are not yet present on the Nepalese market, but inverters used for charging batteries from the grid (for providing power during load shedding periods) are quite common. The market for on-grid inverters is hence still open, their characteristics must be compatible with grid connection conditions, as described in chapter 4.2.2. Compared to the European situation, it is advisable to choose an inverter with a high efficiency at high power in the Nepalese context.
In general, knowhow and appropriate professional skills for grid-connected systems are seriously missing among PV market actors in Nepal. The need for well trained and educated professionals is high, especially among the dealers. However, some basic courses on PV technology are regularly given to professionals as well as students from TU and KU. The course on grid-connected PV technology organized in the framework of this project was the first one in Nepal.
So far, there are no technical standards dedicated to grid-connected PV systems in Nepal, however, there is a standard for components of PV systems that was developed by AEPC in 2000 (NEPQA, the third revision of which is currently in force) (see chapter 4.2.6).

Currently, allocation of responsibilities with regards to the development and management of different sources of energy is spread over several recently constituted ministries and agencies (June 2009). The Ministries deal with their own areas of operation and therefore, policies are not always consistent, and opportunities for inter-linkages and synergies are missing (see chapter 5.1).
The actual legal framework does not foresee the possibility of connecting PV plants to the grid. However, this is the case concerning other alternative energy sources such as wind and biomass. Standalone PV systems are authorised and benefit from subsidies, like other renewable sources (see chapters 5.1.13, 5.1.14 and 5.3.7).

The national electricity production scheme is largely dominated by hydropower, only a very small share is produced by thermal plants. Only part of the country is covered by the electricity distribution network, which deserves the urbanized areas of central Nepal, the southern plain of Terai, and progressively some regional centres in the hills. So far, an important share of the rural population remains without access to electricity (see chapter 5.2).
Most of the generated electricity in Nepal is sold within the country, only less than 10% is exported to India. Nepal also imports part of the electricity it consumes from India (about 412 GWh in 2008). The main consumers of electricity are private households (42% of the sold energy) and industries (40%), the remaining 18% are shared between commercial (7%), non-commercial (6%), water supply and irrigation (2%) and street illumination (3%). The electricity consumption is dominated by a large number of very small household connections (95% of the consumers) and only 5% of bigger industrial consumers. The average total consumption growth over the last decade is 8% per year. Despite the drastic energy consumption increase during the last years, consumption per capita remains extremely low in Nepal (80 kWh/year) (see 5.3). The load curve shows two peaks, one between 6 am and 9 am and the other one, considerably bigger between 4 pm and 9 pm (see 5.2.2).
The electricity distribution grid presents a very high level of loss (about 26%, of which ~19% in the distribution system, ~ 5% in the transmission system and about 1% in the generation system). The grid is characterized by a weak stability, frequent accidental cuts of power and regular planned load shedding schemes that, during the dry season, can reach up to 16 hours a day. The problem of load shedding has become drastically worse since 2005. The demand growth cannot be covered by the production capacity because of insufficient development of the latter, important losses of the system and insufficient capacities of hydro reservoirs. The seriousness of the load shedding schemes is creating severe socio economic damages in Nepal (see chapters 5.2.4 and 5.3.4).
The average cost of the NEA owned generation system is 2.76 NPR/kWh (about 0.039 CHF/kWh). The average production cost of IPPs is about 5.08 NPR/kWh. Indicatively, NEA production cost from hydropower plants is about 1.90 NPR/kWh, and from thermal diesel plants it is about 31 NPR/kWh (about 0.44 CHF/kWh). The selling cost of electricity is relatively high compared to households' revenues. In fact, the cost for small consumers (< 250 kWh/month) is of 9.90 NPR/kWh (0.14 CHF/kWh) and a lower-middle class monthly salary is about 9'000 NPR (130 CHF) (see chapter 5.3).
The GoN has introduced an incentive scheme to sustain the development of renewable energies such as biogas, micro-hydro, standalone solar, wind and improved cooking stoves. For domestic users, solar home systems (SHS) are subsidised through a financial contribution that varies from 5'000 NRP to 10'000 NRP, depending on the size of the plant and the location (remote or accessible). For public institutions (schools, VDC buildings, health posts, etc), the contribution is of 75% of the investment cost. For very small SHS (2 to 5 Wp), the contribution is of 50% of the cost (maximum 1'250.- NRP) (see chapter 5.3.7).

The main stakeholders of the energy sector in Nepal were consulted through interviews and workshops, in order to provide an overview of their opinion on the specific issue of grid-connected PV technology in the country. Senior representatives of public as well as private sector institutions and companies participated in the consultation process. Most of the representatives basically agree on the fact that grid-connected PV technology is appropriate in the Nepalese context, that it has good chances to become a reality in the coming years, and that they would support its implementation. However, people are aware of the fact that this technology would not be able to resolve the current energy crisis alone, and various obstacles have been identified that presently hinder the development of grid-connected PV technology in Nepal (chap. 5.4).

The potential domestic users' point of view has also been investigated in order to understand their perception and experience on related issues, such as their way to manage power supply during load shedding periods, their willingness to pay (and how much) for a secure, 24-hour-per-day power supply, the type of electric appliances they use and their relative importance, the availability of space on their roof and their willingness to host community solar plants on the roof, the way load shedding periods disturb their daily life and the importance they give to the issue of sustainable energy for Nepal. A selected group of 319 households from the middle upper class of Kathmandu responded to the questionnaire. Among the salient findings, it appears that the majority of this category of population (54.5%) presently makes use of inverter-battery systems to manage the access to power during the load shedding periods, and that there would be sufficient available space on roof tops for PV plants installation. Another interesting finding is that more than half of this category of people say that they consider the sustainability of the energy sector to be important, they would like to do something to improve it, but do not know how. The detailed results are presented in chapter 5.5.

Similarly, the industrial and service sectors' points of view were investigated through the interview of 54 companies. 45% of them use diesel gensets, and 38% use inverter-batteries systems to supply power during the load shedding periods. A large majority of them (62%) are ready to pay 40 NRP/kWh for a secure 24-hours-per-day power supply, which is about 6 times more than the present average cost of electricity, 6% are ready to pay more than 50 NRP/kWh, and 28% are ready to pay 20 NRP/kWh. This clearly demonstrates that the private economy sector has understood the importance of access to power for their activities. They are aware of the value of electricity and would be ready to invest in safer and trustable energy production solutions even if the cost were higher. Besides, the awareness of the industrial and services sectors on the importance of a sustainable energy supply scheme in Nepal is also bigger compared to the awareness of the domestic users on the same issue. In fact, 61% of the industries and services claim to be convinced that sustainable clean energy is necessary in Nepal and that their company should concretely do something to make this happening. Another 33% of them think that the issue is of importance, they would be ready to do something but they do not know how. More details are presented in the section 5.6.

The feasibility of grid-connected PV technology has been then assessed considering technical, economic as well as institutional criteria.

Technical feasibility considers issues such as the local climatic conditions, the national electricity grid conditions and characteristics, the availability and characteristics of the various components of PV grid-connected plants including issues related to their certification, the potential energy production of the systems (through simulations) as well as the situation of the education in the related fields.

The salient findings regarding technical feasibility are listed here below (see chapter 6.1 for more details).

- The yearly intercepted solar irradiation in Nepal is easily predictable.
- Climatic risks such as hail, strong winds, tornados etc. are very rare and thus don't need to be considered.
- Horizontal yearly irradiation in KTM is high: **1950 [kWh/m^2/year].**
- With an optimal 30° tilted angle, a solar PV module receives a global irradiation of 2'224 [kWh/m^2/year]. Thus the return on investment time of a standard grid-connected plant will be about half what it is under central European conditions.
- Two-axis annual intercepted global solar irradiation is 2940 [kWh/m^2]. The high incident solar energy intercepted with a two-axis system could be beneficial for medium-large solar PV installations. However, the decrease in module costs makes this solution less interesting.
- Dust and pollution in the KTM region require regular cleaning of PV modules.
- Standard solar PV modules for SHS are available in Nepal. There is a high probability that the cost of solar PV modules will reduce considerably with time, it should therefore be checked continually.
- NEPQA 2009 requires that the "full test report" of IEC tests for imported solar PV modules be provided, a condition for obtaining VAT reduction (2.5% instead of 13%). This condition is contrary to the practice in other countries of the world. In fact, full test reports of this kind contain confidential information on modules' construction, and thus the main producers most certainly will not provide these reports to a non-certified ISO45011 institution.
- Thin film solar PV modules are complex, and the measurement of their characteristics requires specific equipment and knowhow that are not yet available in Nepal. RETS laboratory should receive support in this domain in order to allow this technology to be adopted in Nepal. If the testing of thin film modules is not made possible, these would be penalized because they could not benefit from VAT reduction.
- Inverters for the grid-connection of solar PV plants are not yet available in Nepal. The setup parameters of currently available inverters would need to be adapted to the parameters of the Nepalese grid. The adaptation of such parameters can be easily realized by the importers of the inverters.
- During the dry season in particular (February – June), both during morning and evening peak hours as well as during off-peak hours, the grid cannot provide the required energy. The lack of power is approx. 50%. Solar PV arrays, with their main power production peak during the mid-day hours, could minimize the daily energy shortages significantly.
- Since load shedding affects the capacity of a grid-connected solar PV installation to deliver power to the grid, the first installations of this kind should be placed in locations where the phenomenon does not occur, such as hospitals, NEA buildings, etc. For other areas, it is possible to consider systems that

combine grid-connected PV systems with a local energy accumulation/storage facility, such as e.g. batteries.
- The simulations carried out in this study demonstrate that the productivity of grid-connected solar PV plants in the Kathmandu Valley would be high.
- There is no specific professional training or course on grid-connected solar PV systems. It is necessary to promote practical knowledge on solar PV energy grid-connected, feed-in systems. Promotion should also take place in universities, so as to train competent planners and installers for the future.

Economic feasibility was assessed through a comparative cost analysis of the following 7 electricity production systems in the context of Kathmandu:

1. SHS (Solar Home System) – 1kWp PV modules, 800Ah Batteries
2. inverter with 600Ah of batteries,
3. inverter with only 100Ah of batteries,
4. petrol genset of low quality and
5. petrol genset of high quality,
6. grid-connected photovoltaic installation with back-up system. – 1kWp PV modules, 800Ah Batteries
7. grid-connected photovoltaic installation without back-up system (standard grid-connected system). 1kWp PV modules

The main findings of this analysis is synthesised below (see chapter 6.2 for more details):

- With solar PV plants (SHS and grid-connected systems), the amount of energy produced is (would be) high in the context of Nepal. In the case of grid-connected systems, the energy is fed into the grid, and thus contributes to improving the energy availability in the country, which in turn also contributes to the improvement of the economy and employment situation.
- In the case of genset systems, the energy is produced only during the load shedding period and for immediate energy demands. The fuel must be imported, which aggravates the already poor economic condition of the users and the country. Besides, diesel supply is very insecure in Nepal, and the way costs will evolve is uncertain.
- In the case of inverter-batteries systems (currently the most commonly used technology to compensate for the loss of power during load shedding), no additional energy is produced to be fed into the grid. On the contrary, the energy required to charge the battery bank (considering the low efficiency of batteries and the inverter) has to be taken from the grid, thus worsening the load demand from the grid. Thus, this approach in fact worsens the situation and further reduces energy availability in the country.
- Initial investment costs of solar PV systems are higher compared to the initial investment costs for a grid or genset powered inverter-battery back-up systems.
- However, the cost of the **energy supplied** with a solar PV system is clearly lower compared to grid or genset powered inverter-battery back-up systems.
- In particular, despite of the high initial investment, the cost of the energy produced with a grid-connected solar PV plant is competitive even when only 50% of the investment is paid cash and 50% is financed through a loan with 9% mortgage rate.

The **institutional feasibility** was assessed through the study of existing official documentation on the energy sector organization and legal framework as well as through structured consultations and workshops gathering the main stakeholders of the energy sector in Nepal, both from the public and private sectors. The necessity of increasing the electricity production capacity in the country is generally recognized within the institutions and the idea of implementing grid-connected technology is in principle welcomed and even supported by most of the stakeholders. However, several institutional obstacles have been identified and would need to be overcome in order to make this happen:

- The present legal basis does not allow the connection of PV systems to the grid and would need to be adapted;
- The current standards and norms do not yet cover yet the specific components of grid-connected technology, in particular the inverters and would need to be adapted;
- Politicians and decision makers need to be more aware of the technology's potential and advantages; they need clear evidence of its appropriateness in the Nepalese context in order to support its development.

Regarding this last issue, the discussion is closely linked to the question of national strategic development of the overall electricity production scheme. The GoN plans are oriented towards the construction of new hydro power plants as the main production source for domestic energy. The problem is that medium to large scale hydro power plants take a relatively long time to be implemented (estimated 10 years in a politically stable context, which is currently not the case). The construction of thermal (diesel and coal fuelled) power plants could theoretically be realized in less time in order to compensate for the missing production capacity, but they have the enormous inconvenience of being totally dependent on foreign countries for their fuel supply, something that can become very unsure, as recent experience has demonstrated. Moreover, such thermal plants are characterized by low efficiency performances, high environmental impacts and expensive energy production costs (about 31 NPR/kWh in 2006), which will probably be subjected to high inflation in the coming years. A major diversification of electricity production sources is thus advisable, and can be progressively realized through the development of renewable technologies such as wind, biomass, solar and of course small and medium scale hydro-power plants. In this perspective, the use of solar PV grid-connected systems could play an important role, and the responsible institutions should consider it as one of the components of the future energy mix, and thus to be included in the development of the energy policies of the country.

The conclusion shows that there is a very encouraging potential feasibility of PV grid-connected technology in the Nepalese context. In fact, the analysis demonstrates that most of the identified obstacles can be overcome, and that this technology could effectively participate in the improvement of the energy sector in the country, and help solve the current energy crisis.

It has been demonstrated that solar PV grid-connected systems would benefit from the excellent climatic conditions in Nepal, something which would provide additional value to the solar energy technology, both in terms of production capacity as well as cost effectiveness. In fact, compared with Southern Germany, the solar energy received on a module’s surface is 74% higher in Kathmandu. Besides, the contribution of solar PV grid-connected systems to partly resolve the problem of load shedding (lack of electricity production capacity) has been demonstrated by the fact that it would allow to reduce the load, thanks not only to the reduction of consumption by the users, but also thanks to the additional injection of energy into the grid. Moreover, compared to other alternatives for increasing the electricity production capacity in the country, solar PV grid-connected systems presents the following advantages:

- They are very efficient, in terms of productivity (kWh/kW installed capacity) in Nepal’s good and favourable climatic conditions (high annual solar insulation);
- They can be rapidly implemented (in a matter of weeks or months rather than the years needed to implant hydro power plants);
- With their “fuel” being a renewable energy resource, solar PV systems are independent from the need of an external, often fossil, energy source (like diesel or coal). This not only means the “fuel” of a solar PV system is easily available to anyone free of cost, but it is also positive for the important issues of the country’s energy security, unpredictable fuel cost curve and inter-political tension;
- They provide interesting professional and local economy opportunities in terms of employment, education and new business ventures;
- They have a very small carbon footprint and once installed and running are environmentally very clean;
- with regards to effects on the grid, they are very appropriate, and in fact very supportive to the grid compared to present alternatives used for dealing with the load shedding periods (genset, inverters + batteries). Solar PV grid-connected systems support the grid in various ways rather than weakening it;
- They are becoming more and more economically competitive compared to present alternatives used to deal with the load shedding periods.

However, there are still various obstacles that need to be addressed before the technology becomes fully implementable, as developed in chapter 6.4.

The study has also permitted to elaborate some recommendations aiming to facilitate the progressive introduction and development of PV grid-connected technology in Nepal. These consider issues such as the legalisation, the adaptation of norms and standards, the necessity of communication and demonstration of the technology’s potential, the reinforcement of education in related fields, and finally the market stimulation. Those recommendations are presented in chapter 6.4.
It is a matter of fact that the introduction of a new technology, such as grid-connected solar PV systems, often faces initial resistance from key stakeholders and individuals. This happens partly because of the lack

of knowledge and familiarity with the new technology. In the case of grid-connected solar PV systems, the fact that it has been implemented with great success and since many years in various countries must be considered, and thus will play an important role in the raising of awareness.

The obstacles that are still hindering the applicability of grid-connected technology in the Nepalese context, as analyzed in the present report, have to be addressed in order to take advantage of this sustainable energy source in a near future in Nepal.

In this perspective, the realization of PV grid-connected pilot plants would certainly be of great value in demonstrating and monitoring the qualities and risks of such application in the particular context of Nepal. In any case, it represents a necessary step towards larger scale dissemination, as it has successfully been demonstrated in many other nations.

2 Introduction

2.1 Background

This project was co-funded by REPIC and SUPSI. It was achieved through the close collaboration between SUPSI and two Nepalese partner teams: the CES of the Tribhuvan University together with NSES, and Kathmandu University alongside RIDS-Nepal. The project was implemented between October 2008 and June 2010.
Although connecting PV modules to the main electric grid is by far the most rational, economical and efficient way to install this technology, it appears that, like in many other developing and transition countries, PV technology has so far been applied in Nepal exclusively through standalone plants (NEA, 2008). Such plants are used in several remote areas of the country and provide very satisfactory service to the rural populations (Zahnd, McKay, & Komp, 2006). However, the urban regions of Nepal, which already have access to the national electricity grid, are so far making use of PV technology without the added advantage of a connection to the grid. As exposed in chapter four, Nepal benefits from extremely favourable climatic conditions for exploiting PV technology. Moreover, despite its extraordinary potential for the production of hydropower, a lack of investments, political instability and the increase in energy demands have brought the country in a severe energy crisis, with as much as sixteen hours of load shedding per day during spring 2009. Solutions and ways out of the energy crisis will certainly be found by diversifying the electricity sources, so as to increase the production capacity in the short and long term, with –hopefully– careful consideration for global sustainability criteria. Grid-connected PV technology could be part of the “package” of Nepal’s future electricity supply scheme, but the conditions and criteria to make it applicable in the given context are manifold and influenced by technical, institutional and economic aspects. These will be analysed in the present work in order to assess its feasibility. Although the investigation for the development of alternative energy sources is a fundamental and acknowledged issue for the energy sector in Nepal, the present study is the first to look specifically at the feasibility of grid-connected PV in the country. The reference context considered in this study is the Kathmandu Valley.

In parallel to the feasibility study, a training programme was conducted for TU and KU students at various phases of the project. Moreover, both TU and KU students were directly involved in the study activities, mainly to conduct surveys with potential domestic and industry/service technology users.

2.2 Methodology

The following organisation has been chosen for the information and data to be researched for the feasibility assessment:

INFORMATION / DATA to collect	PROCEDURE
Climatic conditions	Collection of existing data from various sources (ch. 4.1)
Professional sector characteristics	Analysis of professional capacities and organization (ch. 4.2)
Institutional setup	Analysis of official documents related to the organization of the energy sector, interviews with stakeholders, and organization of a workshop bringing together the main stakeholders of the public and private sectors (ch. 5)
Condition and characteristics of the national electricity grid	Analysis of NEA documents and data from various sources (ch. 5.2)
Economy of the energy sector in Nepal	Analysis of NEA documents and data as well as survey results with potential users (ch. 5.3)
Main stakeholders’ point of view	Semi-structured interviews with the main actors of the energy sector (ch. 5.4)
Domestic users’ point of view	Survey with 319 potential users (ch. 5.5)
Industrial and service sectors’ point of view	Survey with 54 potential users (ch. 5.6)

All data and information has been analyzed in order to establish to what extend grid-connected PV technology is feasible in Nepal in consideration of the following three main criteria:

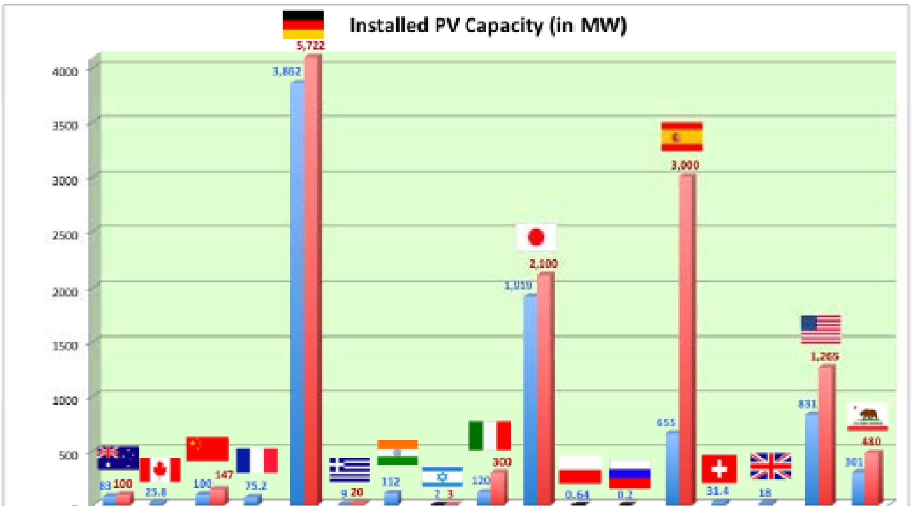
1. Technical feasibility
2. Economic feasibility
3. Institutional feasibility

This methodology was developed and implemented in close collaboration with the project's three partners. The main activities and milestones are resumed below, along with the time frame in which they took place:

ACTIVITIES	PLACE	TIME FRAME
Kickoff meeting	Nepal	October 2008
Project preparation and secondary data collection	SUPSI	Jan.-Feb. 2009
Field survey launch and interviews with local partners	Nepal	April 2009
Milestone 1: Training programme at TU, part 1	Nepal	April 2009
Primary and secondary data collection by partners	Nepal	April-August 2009
Data consolidation with partners	Nepal-SUPSI	August 2009
Data analysis	Nepal-SUPSI	August-September 2009
Milestone 2: • Training programme at TU, part 2 • Final workshop with actors of the sector • RETSUD International conference	Nepal	Nov. 2009
Final report writing	Nepal-SUPSI	December 2009-June 2010
Milestone 3: Final report submission	SUPSI	21 June 2010
Results dissemination	-	June 2010 onwards

3 PV grid-connected technology in the World and in Developing Countries (Current state)

In 2008, the world PV market grew by more than 80% in terms of production, reaching approximately 7.35 GW. The market for installation systems nearly doubled, climbing up to 5.6-6 GW. These figures are mainly accounted for by grid-connected PV systems throughout the world. Off-grid PV systems represent about 1.75 GW (~30% of the total installed power) (JRC, 2009). Figure 1 shows an overview of the installed PV capacity around the world. Experiences with grid-connected PV systems and different models of feed-in tariffs in developing as well as in European countries will be presented within this chapter.



	Australia	Canada	China	France	Germany	Greece	India	Israel	Italy	Japan	Poland	Russia	Spain	Switzerland	UK	USA	California
end 2007	83	25.8	100	75.2	3,862	9	112	2	120	1,919	0.64	0.2	655	31.4	18	831	301
end 2008	100		147		5,722	20		3	300	2,100			3,000			1,265	480

Figure 3-1: PV capacity (MW) of 17 different countries

The Chinese PV market more than doubled in 2008, increasing by 45MW, yet the domestic market still represents less than 2% of the total PV production. This situation could change in the future however, since the government has launched its “green energy programme” for a total cost of approx. RMB 210 billion (€ 22 billion). This programme includes a subsidy of 20 RMB/Wp (2.10 €/Wp). The target is to reach a total installed PV capacity of 20 GW by 2020. However, most of the installed PV power in China is generated by off-grid plants (95%), with only a marginal amount of the power installed so far being connected to the grid.

In 2008, the Indian government introduced the India’s first “National Action Plan on Climate Change”. The use of solar energy with PV is described in the “National Solar Mission”. This document envisages an installed solar generation capacity of 20 GW by 2020 and of 100 GW by 2030. At the end of 2008, most PV applications in India were off-grid (solar lanterns, solar home systems and water pumping systems). Only 33 solar PV systems were grid-connected, with a total installed capacity of approximately 2 MWp. This corresponds to approximately 2% of the 100MWp installed PV capacity. In the 2008-2012 five-year plan, India aims to install 50MW grid-connected PV systems, a goal that the Ministry of New and Renewable Energy supports through an investment and a power purchase programme. The national cap was fixed at 15 Rupees per kWh for grid-connected solar PV projects. This could vary slightly in different states. For instance, Bengal offers a rate of 11 Rs/kWh. The generation-based incentives will be available for a period of 10 years starting from the date of commissioning.

In Brazil, the first grid-connected and building integrated photovoltaic system was installed in 1997 at LABSOLAR (Laborationo de Energie Solar, Florianópolis). This is a 2kWp, glass-glass, thin-film a-Si (array surface 40 m^2) integrated and continuously monitored installation (Oliveira, 2001). Oliveira’s study concentrated mainly on the correspondence between electrical utility’s urban feeders, load curves and the generation profiles of these grid-connected PV Systems, so as to limit demand peaks.
Brazil has a centralized energy generation model whose main source is hydropower plants. This entails a high loss, complex, extensive and expensive transmission and distribution system. Energy is delivered in a large number of scattered urban centres, where 80% of the population lives. The high number of commercial buildings is responsible for most of the power demand peaks during daytime (air conditioning). These loads are typically related to a situation of high solar radiation. In such context, PV systems could support the power supply system in reducing demand peaks. Since 1997, four grid-connected PV plants have been

installed and monitored. The potential of these grid-connected PV plants was studied in terms of daily energy yield and the matching of load profiles with PV generation profiles. The study showed that PV systems can significantly reduce demand peaks and contribute to the stability of the power supply system (Ruther, 2005).

In Malaysia, the first grid-connected PV plant was installed in July 1988, on the rooftop of the College of Engineering, University Tenaga National (UNITEN). The installation's capacity is 3.15 kWp, and it is connected to the three phases electricity system of the building (Haris, 2006). This installation is the first Malaysian practical experience with grid-connected PV. Even though it has some technical problems, the system is still working today. During the same year, two other grid-connected PV systems were installed respectively by BP Malaysia and the University Kabangsaan Malaysia (UKM). An 8 kWp PV system was installed at a BP petrol station along the KESAS highway and a 5.5 kWp PV system at the Solar Energy Research Park in UKM. The two latter systems have however recently been removed.
Today, the grid-connected BIPVs installed in Peninsular Malaysia amount to almost 500 kWp, the most remarkable one being the 362 kWp BIPV at the Technology Park Malaysia. All these installations have shown Malaysia's capability to handle and manage large PV installations. Malaysia already has extensive experience with standalone PV (more than 2 MWp of installed capacity), and grid-connected PV applications (about 500 kWp of installed capacity). There are several studies that show the viability and reliability of Malaysia to produce 1.3 times more PV electricity than Germany, and the BIPV sector has the technical potential to generate 7.8 TWh of electricity, a figure equivalent to 21% of the residential and commercial electricity demand in 2005.

In Indonesia, a pre-feasibility study on the "Development of Grid-Connected Photovoltaic for Urban Area" has been carried out (Chazaro-Gerbang-International, 2005). PV systems in Indonesia are currently dedicated to satisfying small electricity demands in rural areas. Considering the purchasing power of rural communities and the high up–front cost of photovoltaic systems, such applications can only be built under government subsidy programmes. The overall scope of the project covers grid-connected PV systems in the urban context, where they can be economically and practically installed both for self-consumption and for export to the grid. The main objective of this project was to investigate the economic viability of wider scale grid-connected PV plants for urban residential and commercial sector applications. The project is expected to serve various purposes:

- Public awareness: the problem that PV systems are considered by most people and decision makers as an interesting technology for rural areas only, where there is no other available energy source, should be solved by introducing PV applications in urban environments. Indeed, this would help establishing an understanding among the general public that PV systems not only provide electricity, but also that they are a clean source of energy.
- Economic development: the project was expected to serve as a communication tool to justify the economic viability of grid-connected PV applications.
- Technical capacity building: the project intended to provide a teaching tool for Indonesian engineers and manufactures on grid-connected PV systems.
- Institutional capacity building: Institutional strengthening and cooperation among stakeholders, including electricity utility companies, individual and private project developers, financial institutions and related government bodies, with respect to financial and legal aspects of power purchase as well as pricing policy.

The results of this study demonstrated that grid-connected PV technology for urban areas is both technically feasible and economically viable. Furthermore, discussions with the government and research institutions as well as with utility companies have revealed a high interest in the proposed project. The 1000 kW of grid-connected PV power plant would supply 1.223 MWh of electricity per year to the Java-Bali grid, the reduction in CO_2 emissions would reach 795 tons per year, and the annual income from selling electricity to the national grid was estimated at more than US$100,000.
The project intended to provide the following benefits:

a. Reduction of the environmental impact of energy generation
b. Reduction of GHG emissions
c. Improvement of public health
d. Creation of new job opportunities
e. Technology replication and dissemination in other locations throughout Indonesia.

The project's financial performance was indicated to reach only 2.31% of the financial internal return rate. Hence, the project was not financially viable. However, after incorporating all the externalities in the economic analysis, the project showed the potential for achieving a significant economic benefit. Indeed, an EIRR (Expected Internal Rate of Return) of 12.07% was obtained, indicating a benefit to cost ratio greater than 1. This leads to the conclusion that the project is in fact economically feasible.

In Nepal, a small Building Integrated Photovoltaic Electric System (BIPVES), connected to the grid and consisting of 100 numbers of 65 Wp PV modules, 220 x 2V, 468 AH lead acid batteries, and one 15 kVA Grid Interactive Inverter, was commissioned in 2003 at the Centre for Energy Studies (CES) of the Institute of Engineering (IOE) of Tribhuvan University, Lalitpur. The daily electrical energy generated is about 27 kWh, enough to meet the electrical energy demands of the CES. The system functions perfectly well, even with 16 hours of load shedding per day. One of the main objectives of this plant was to demonstrate to students studying Photovoltaic Technology at IOE how excess energy stored in batteries during sunny periods of the day can be transmitted to utility grid. However, local authority did not allow this procedure, as Nepal still lacks law/regulation for PV grid connection. CES has been unsuccessfully lobbying for this regulation since 2003. (Shrestha J. , 2010). A picture of this plant is shown in chapter 7 (Fig. 7.1).

Europe has the most experience with grid-connected PV plants and with feed-in tariffs, especially Germany who has the highest amount of installed PV. The electricity consumption from renewable sources in Germany will represent 12.5% of the total consumption in 2010 (excluding large hydro); the goal for 2020 it to reach 27%. The total installed PV plant capacity was 3,862 MW in 2007 and 5,722 MW in 2008 (99% grid-connected). Germany has applied feed-in laws since 1991. The current feed-in law, 'The Renewable Energy Sources Act (EEG)', has been applied since 2000 (BMU, 2009). It was preceded in 1999 by the '100,000 roof' programme, which aimed to generate the installation of 300 MWp of PV through a 35% subsidy for PV systems (with 0% interest rate loans and a feed-in tariff of 0.457 €/kWh by 2003). The subsidy ended in 2003 with 346 MWp of installed power. In 2004 a new EEG was launched, with a guaranteed rate of 0.574 €/kWh (plants <30 kWp, 0.54 €/kwp >30 kWp) for 20 years with no cap on system size. The annual degradation rate was 5% for rooftop and façade installations, 6,5% for ground-mounted systems. In 2009, the degradation rate was adjusted. The law now stipulates that the degradation rate will be applied in function of the annual growing rate of new installations. The limit is fixed between 1000 and 1500 MW for 2009; if an installation exceeds the upper limit, the rate will increase from 8% to 9%. If an installation goes under the lower limit, the rate will decrease by 1%. Offers for subsidized loans were provided by the loan programme 'Solar Power Generation', with a rate of 5.2% for 5 or 10 years.

The United Kingdom does not have a feed-in tariff because early approaches have been dropped. Instead, a 'Low Carbon Buildings Programme' was developed. This programme proposes financial grants to promote the installation of low carbon technologies in households, in the public and the private sectors. There is no PV-specific programme. So far, this programme has not been an effective mechanism to increase the installation of PV plants. The total PV capacity in 2007 was only 18 MW (91% grid-connected) (Kravetz, 2008). The annual installation growth rate was 10.3% between 2006 and 2007, but in 2007 no PV plant was installed. To achieve the target of producing 20% of electricity through renewable energies by 2020, the queen gave her assent for a feed-in law to be implemented before the end of 2010.

Spain is the most active country in the development of solar energy. It has more available solar energy than any other European country. The yearly average solar yield is of approximately 1300 kWh/kWp/yr (Germany's solar yield is of 950 kWh/kWp/yr). In the last years, Spain has build a large number of MW PV plants, as for example the *Parque Fotovoltaico Olmedilla de Alarcon* (60 MW) in 2009 (PVResourses, 2009). Spain's total grid-connected PV capacity was 3405 MW in 2008 (EurObserv'ER, 2009). The Spanish government is committed to achieving the target of 12% of primary energy produced from renewable energy sources by 2010. In 2004, the Spanish government removed economic barriers to the connection of renewable energy technologies to the electricity grid and guaranteed a feed-in tariff of 0.34 €/kWh for rooftop systems.

4 Context analysis

In order to realize grid-connected PV plants, climatic aspects (global irradiation, temperature and wind conditions) as well as technical aspects (grid, modules, inverters and other equipments characteristics) have to be considered. Additionally, economic, institutional and market frameworks influence the viability of the technology and must also be considered.

4.1 Climatic conditions

The climatic information needed for sizing a grid-connected PV plant and for predicting its energy output are:

- Global Horizontal Irradiation (GHI);
- In-plane Global Irradiation at different orientations, and the ambient temperature (minima and maxima);
- Level of smog and dust in urban and rural areas (in order to foresee necessary instruction for maintenance and cleaning of the modules' surface);
- Wind conditions (necessary to construct appropriate support structures).

In the framework of this study, only the urban areas of Kathmandu valley are considered, it is thus not necessary to calculate the horizon to assess the shadow generated by the hills.

4.1.1 Sources of climatic data

GON started carrying out hydrological and meteorological activities in an organized way in 1962. Since 1988, these have been under the responsibility of the Ministry of Environment, Science and Technology, Department of Hydrology and Meteorology.

The DHM, as well as its headquarters in Kathmandu, has three basin offices: Karnali Basin Office in Surkhet, Narayani Basin Office in Pokhara, and Kosi Basin Office in Dharan. The Department was given the mandate to monitor all hydrological and meteorological activities in Nepal, and no other agency is entitled to carry out such activities without a proper liaison with DHM. The scope of their work includes the monitoring of river hydrology, climate, agro-meteorology, sediment, air quality, water quality, limnology, snow hydrology, glaciology, wind and solar energy.
DHM maintains a nation-wide network of 337 precipitation stations, 154 hydrometric stations, 20 sediment stations, 68 climatic stations, 22 agro-meteorological stations, 9 synoptic stations and 6 Aero-synoptic stations. Data are made available to users through published reports, bulletins, and computer media outputs. However, the available data at DHM are not sufficient for the calculation of PV systems and have therefore been integrated with data from the following sources:

1) NASA Surface meteorology and Solar Energy Data (considered as the most reliable)
2) Meteosat, SWERA project, DLR final report
3) Measured data (by RIDS-Nepal)
4) Meteonorm

The reference data for Kathmandu were measured in the RIDS-Nepal KTM office in Sanepa, Lalitpur (Latitude: 27°40'04.70" North / Longitude 85°20'31.55" East / Altitude 1311 meters above sea level), and the data for Humla District at the following location: 29°58'22.07" North / Longitude: 81°49'05.63" East / Altitude: 3000 meters above sea level.

4.1.2 Ambient temperature

Temperature has a strong influence on PV module performance. Typically, for a crystalline silicon module, the power temperature coefficient (γ) is between -0.4 to -0.5 [%/°C] (i.e. for +10°C temperature above standard temperature (according to STC), 4-5% of power is lost). In the case of amorphous silicon technology, the power temperature coefficient is between -0.15 to -0.25 [%/°C].

In the case of grid-connected PV plants, it is essential to consider the influence of temperature on voltage. Voltage limits during the life-time of the PV system have to be calculated and compared to the voltage limits of the chosen inverter.
Maximal voltage conditions typically occur during winter mornings: in the early morning the ambient temperature is at its lowest, the PV modules already generate a voltage at the beginning of sunlight, but the inverter is not yet functioning, and therefore the modules will be operating in open circuit (Voc). In these conditions, the inverter's entrance maximal voltage needs to be within the acceptable voltage range.

A non-critical condition for the inverter's safety is whether, at this maximum PV module MPPT, voltage conditions are within the inverter's voltage range.
The opposite situation occurs during maximal summer temperatures, with high incident irradiation on the PV modules, which can lead to overheating. The variation in the voltage corresponds to approximately 2.1mV/°C/cell on Voc. The cell temperature is also influenced by the module's exposure to natural ventilation, and consequently by the array mounting system.
(Vm,min-max: Operating voltage of the MPPT; Condition: Vm @ Tcell, Max and Min annual)

Ambient temperature has to be considered to determine the inverter's functioning limits. An incorrect positioning of the inverter could cause overheating, resulting in unwanted power limitation.

Table 4-1 shows monthly mean temperatures for different climatic locations in Nepal.

	NASA Kathmandu	METEONORM Kathmandu	NASA Jumla (Karnali)	NASA South-Karnali	NASA Pokhara	NASA Simikot (Karnali)
Month	**Ambient temperature**	**Ambient temperature**	**Ambient temperature**	**Ambient temperature**	**Ambient temperature**	**Ambient temperature**
	°C	°C	°C	°C	°C	°C
January	7.2	7.9	-8.7	9.6	0.4	-14.9
February	9.4	12.3	-7.4	11.9	1.9	-14
March	13.8	17.9	-3.3	16.7	6.4	-9.8
April	16.8	24	1.7	20.9	10.8	-4
May	17.9	26.8	6.5	22.4	13.2	2.5
June	19.4	26.3	9.6	23.2	15.1	6.5
July	19.6	24.1	11	22.5	15.6	8.4
August	19.5	23.5	10.8	22.1	15.4	8.1
September	18	22.6	8.2	20.5	13.6	4.8
October	14.8	19.8	3	17.2	9.4	-0.7
November	11.1	14.9	-0.8	13.6	5.9	-4.8
December	8.3	9.9	-4.5	10.6	3	-9.3
Annual	14.7	19.2	2.2	17.6	9.2	-2.3

Table 4-1: Monthly mean values of ambient temperature.

The monthly mean values do not provide sufficient information on temperature for sizing a PV plant, it is necessary to consider minima and maxima temperature values (at least hourly if not available per minute). The minimum and maximum temperatures in KTM are:

- Min. temperature over the last 10 years: ca. -2 [°C]
- Max. temperature over the last 10 years: ca. +38 [°C]

The temperature of the module can be calculated with the following approximation formula:

$$T_{cell} = T_a + \left(NOCT - 20°C\right) * \frac{Gi}{G_{NOCT}}$$

Where:

- NOCT: Nominal Operating Cell Temperature (with Gi=800 [W/m^2]; Ta=20 [°C]; wind speed=1 [m/s])
- G_{NOCT}: global irradiance at NOCT
- G_i: in-plane global irradiance
- T_a: ambient temperature

NOCT typical values: 44°C to 55°C (open-rack); example value=48 [°C].

Thus, the minima and maxima PV module cell temperatures for the Kathmandu valley are calculated to reach:

$T_{cell,max}$ = +73 [°C] in warm period at noon
$T_{cell,min}$ = -2 [°C] in winter in the morning

Considering the best and worst cases of NOCT, the cell temperature will vary from +68 [°C] to +82 [°C]. With the Meteonorm software, it is possible to synthesize hourly data from average monthly data, resulting in the following limit values:

$T_{a,max}$ = -3 [°C]
$T_{a,min}$ = +42 [°C]

These Meteonorm synthesized data sufficiently correspond to minima and maxima measured data.

4.1.3 Wind Characteristics

Wind characteristics affect the cooling properties of PV modules as well as the loads applied on their mounting structures.
The NOCT (Nominal Operating Cell Temperature) is defined as the temperature of a “freely” mounted (open-rack mounted) module in open circuit under irradiance of 800 W/m^2, at an ambient temperature of 20 °C and a wind speed of 1 m/s. This value is normally rated by the manufacturer of the module. But in fact, NOCT value is related to the value in open circuit condition, which is not suited for grid-connected PV systems. In order to take into account thermal loss in the field related to specific mounting conditions, it is possible to introduce a “Field Thermal Loss Factor” in simulation programs such as PVSYST.

In the Kathmandu valley, wind conditions are not extreme, but on roof-tops installed PV systems the wind’s cooling effect can have an influence.

Monthly averaged wind speed at 50 m above the surface of the earth (m/s)

Lat 27 Lon 85	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	4.46	4.8	5.01	5.01	4.59	3.84	3.04	2.99	3.05	3.77	4.09	4.25	4.07

Minimum and maximum difference from monthly averaged wind speed at 50 m (%)

Lat 27 Lon 85	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Minimum	-12	-15	-13	-11	-19	-20	-12	-8	-10	-9	-9	-6	-12
Maximum	10	16	21	18	16	14	14	9	10	8	9	10	13

Monthly averaged percent of time the wind speed at 50 m above the surface of the earth is within the indicated range (%)

Lat 27 Lon 85	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
0 - 2 m/s	21	16	14	12	11	21	37	38	36	31	28	25	24
3 - 6 m/s	63	67	66	70	75	74	60	60	62	59	61	62	65
7 - 10 m/s	12	13	16	15	13	6	2	2	2	7	6	9	9
11 - 14 m/s	3	4	4	3	1	0	0	0	0	3	5	4	2
15 - 18 m/s	0	0	0	0	0	0	0	0	0	0	0	0	0
19 - 25 m/s	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4-2: NASA wind data for Kathmandu

4.1.4 Global Irradiation

With about 300 days of sunshine per year in most parts of the country and an average of eight hours of light per day, as well as being situated on the ideal 30° North "solar belt", Nepal has very good conditions for the use of solar power. Solar PV modules installed at an angle of 30° South can intercept 4.8 to 6.0 [kWh/m^2] of solar energy on a daily average in most locations throughout the country (Zahnd, McKay, & Komp, 2006).

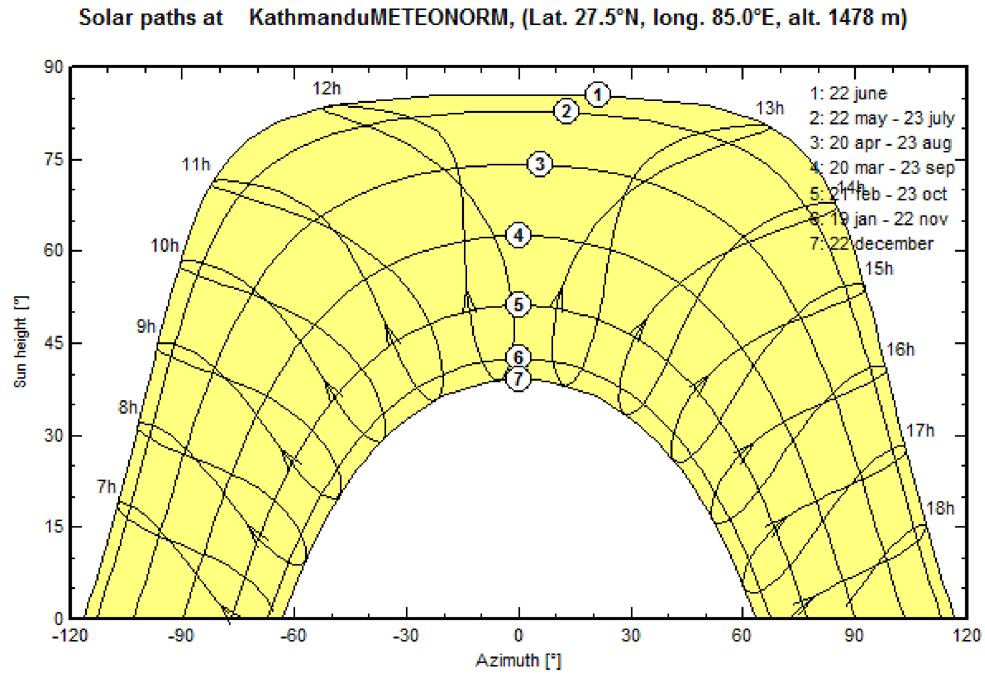


Figure 4-1: Solar path at Kathmandu.

The solar diagram (Figure 4-1) shows the position of the sun throughout the year and at different hours in Kathmandu. The position of the sun at a low elevation (<15°) is found when the azimuth of the sun (orientation) is East (from -110° to -60°) or West (from +60° to +110°). A building or another obstacle positioned at these azimuths could be critical for energy production.

Global horizontal monthly solar irradiation in Kathmandu:

In a grid-connected system, all the available energy is passed into the grid, which means there is no limitation due to battery capacity. Consequently, the most appropriate unit is annual irradiation (in [kWh/m^2/year]), and for the calculation of energy yield, values of monthly irradiation are normally used as basis data (in [kWh/m^2/month]).
Annual irradiation on a horizontal plan can vary substantially during the years. For this reason, it is necessary to consider data measured over decades. Besides, longer term tendencies such as the increase in air pollution, variations in rain regimes and other non measurable factors can also influence the yearly irradiation.
Table 4-3 shows monthly irradiation values generated by Meteonorm and NASA as well as ground measurement values taken by RIDS-Nepal with differences in%.

	NASA	RIDS meas. 2004-05	NASA/RIDS meas 04-05	METEONORM	NASA/METEO NORM	Meas/METEO NORM
	[kWh/m2/m]	[kWh/m2/m]		[kWh/m2/m]		
January	**132.1**	**137.3**	3.9%	**140.0**	6.0%	2.0%
February	**144.2**	**175.2**	21.5%	**145.0**	0.6%	-17.2%
March	**191.6**	**181.3**	-5.4%	**186.0**	-2.9%	2.6%
April	**202.8**	**168.2**	-17.0%	**204.0**	0.6%	21.3%
May	**207.1**	**187.8**	-9.3%	**213.0**	2.9%	13.4%

June	**172.5**	**170.4**	-1.2%	**175.0**	1.4%	2.7%
July	**148.5**	**134.9**	-9.2%	**149.0**	0.3%	10.5%
August	**148.8**	**130.3**	-12.5%	**147.0**	-1.2%	12.9%
September	**136.8**	**148.6**	8.6%	**146.0**	6.7%	-1.8%
October	**159.0**	**171.1**	7.6%	**163.0**	2.5%	-4.7%
November	**141.6**	**185.3**	30.8%	**142.0**	0.3%	-23.4%
December	**128.7**	**186.5**	45.0%	**140.0**	8.8%	-24.9%
Year	**1913.6**	**1976.8**	**3.3%**	**1952**	**2.0%**	**-1.3%**

Table 4-3: Global horizontal monthly solar irradiation in Kathmandu.

The difference between NASA data and those measured by RIDS-Nepal in 2004-2005 is only 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 like PVsyst will be rather conservative, and give prudent results for the final yield of the customer's systems. For a particularly conservative approach, NASA data should be utilized. In the framework of the present study, Meteronorm data will be utilized, with a value of horizontal yearly irradiation of:

GHI ≅ 1950 [kWh/m²/year]

The following graph, used by NREL and DSR projects, shows satellite data from Meteosat, with an average irradiation value equal to 5.5 kWh/m²/d, corresponding to 1825-2007 kWh/m2/y (average 1916).

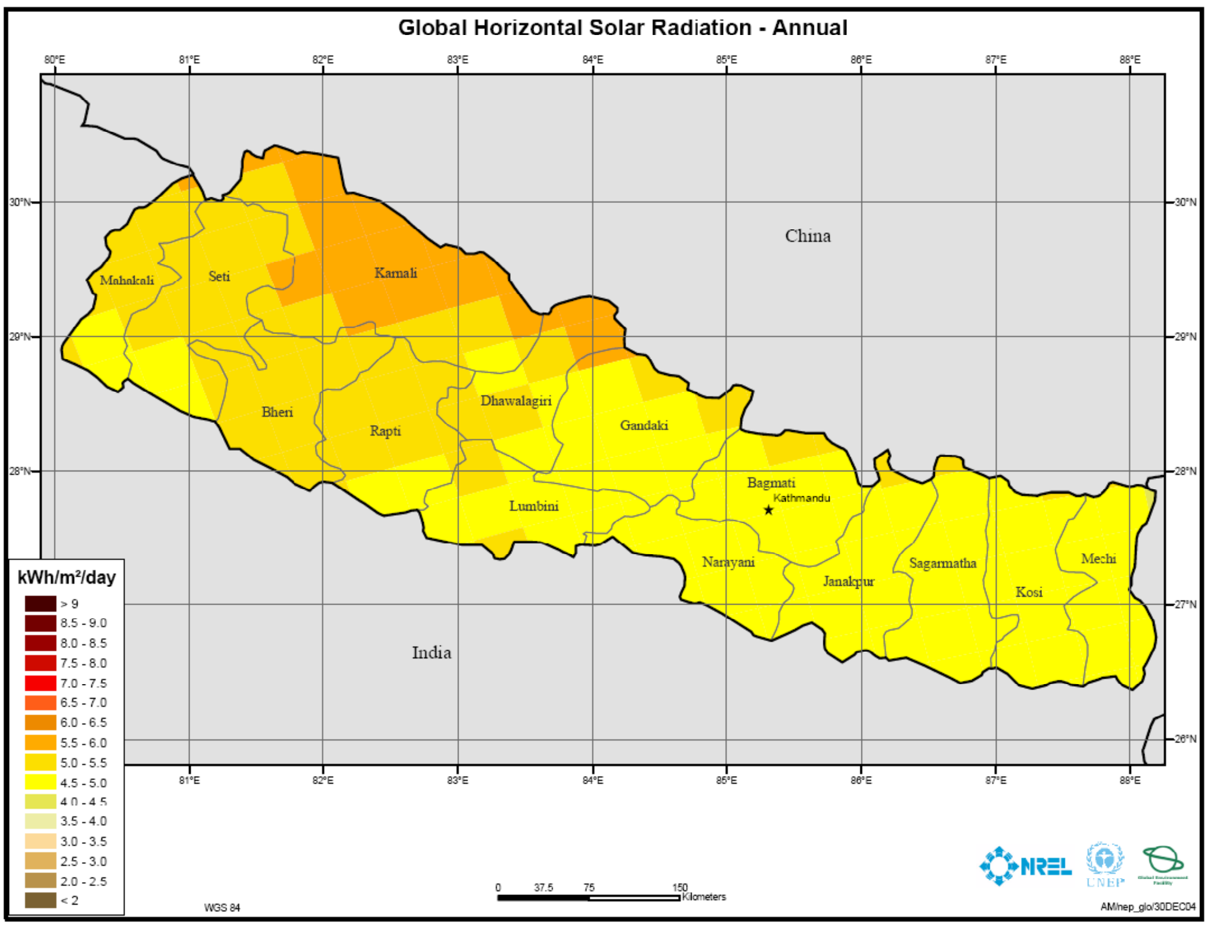


Figure 4-2: Global Horizontal Solar Irradiation [kWh/m²/day] for Nepal (source: NREL)

Optimal tilted angle

The optimal tilted angle for a maximal yearly irradiation can be derived from the transposition factor. The graph below (Figure 4-) shows that the highest irradiation value is obtained with a South oriented plan and a 30° titled angle. However, the ambient temperature has a relevant influence on PV modules behaviour (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. Because of the important presence of clouds and high temperatures, summer is the season when the least amount of PV energy will be produced. Modules tilted with a larger angle (compared to 30°) will produce more energy over the course of an average year. In the framework of this study, we consider a reference titled angle of 30° corresponding to the maximum yearly irradiation value.

Reference tilted angle: 30°

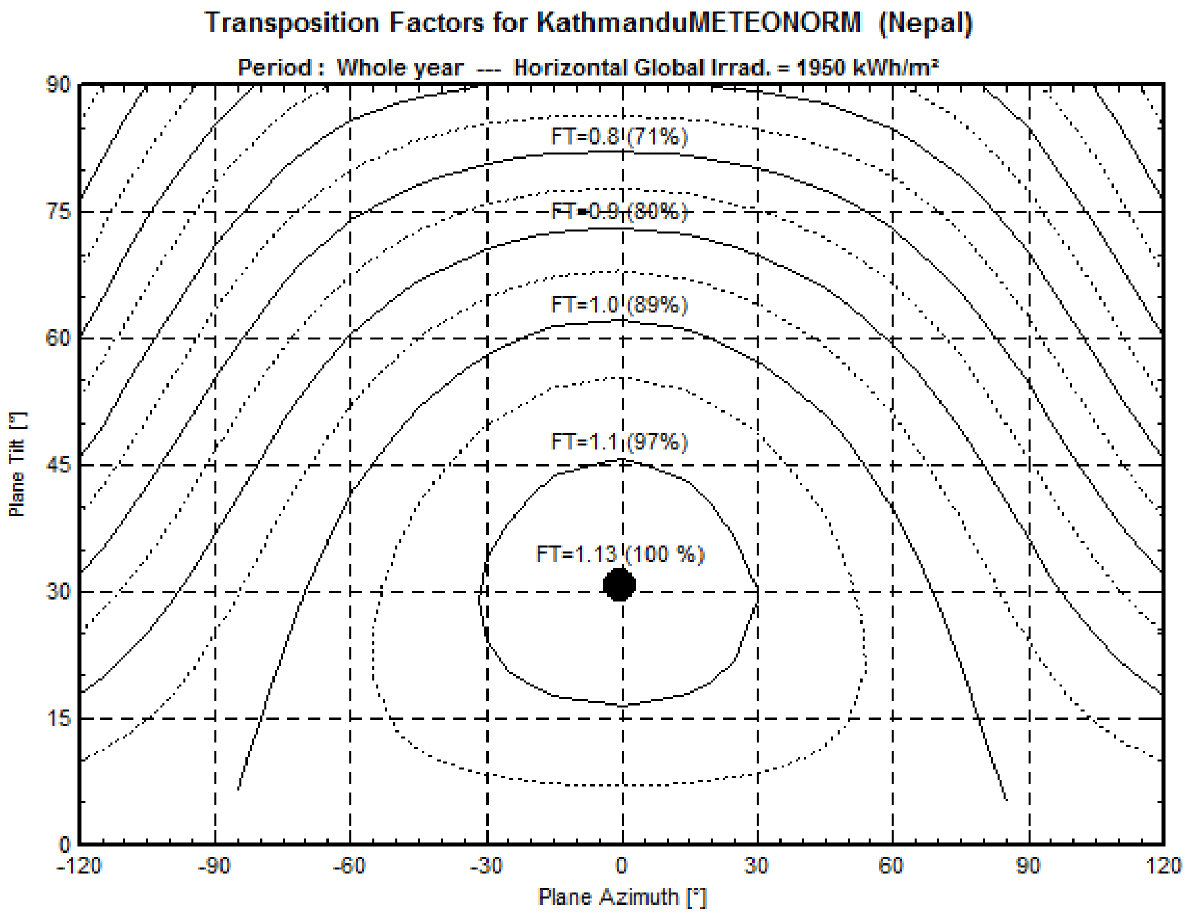
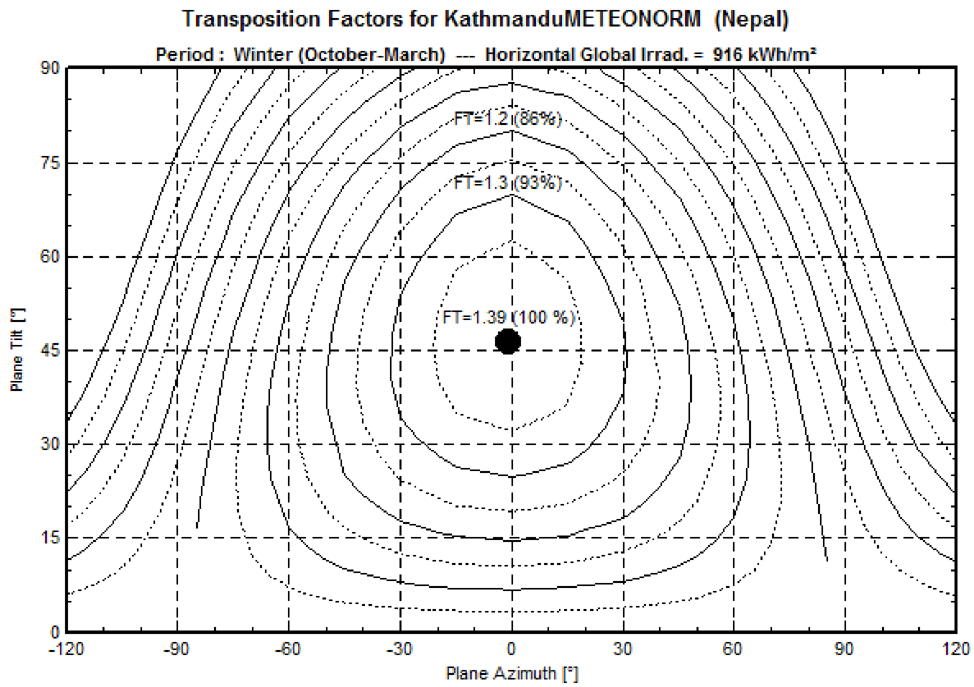


Figure 4-3 (a): Transposition factor for Kathmandu (Nepal).



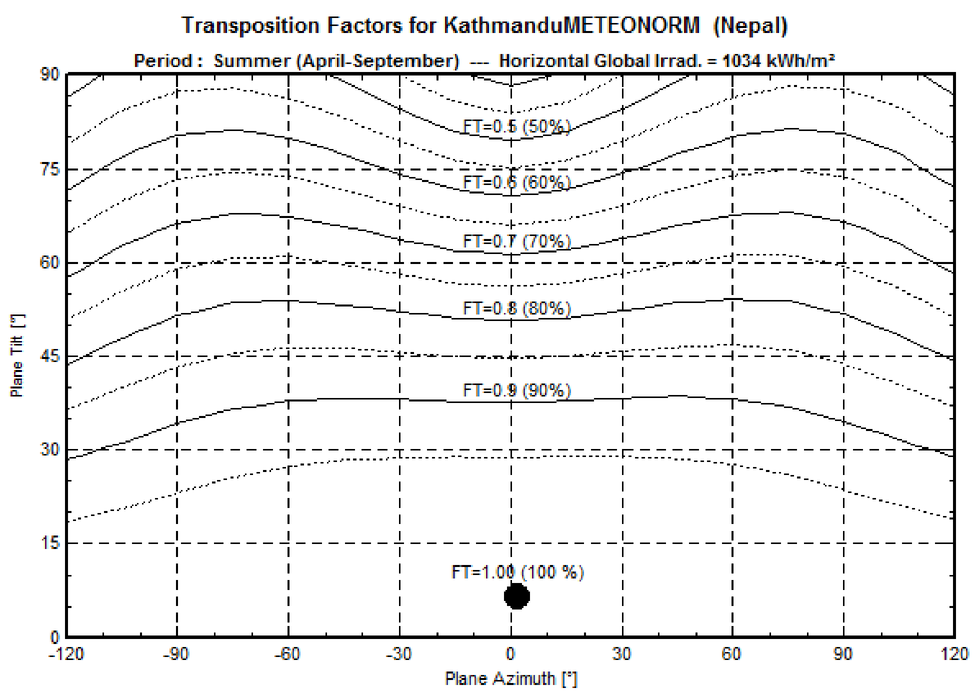


Figure 4-3 (b): Transposition factor for Kathmandu (Nepal).

Global in-plane monthly solar irradiation in Kathmandu:

In-plane global irradiation refers to the intercepted global solar radiation on a defined inclined surface. From the global horizontal monthly solar irradiation, it is possible to calculate the tilted global monthly value. This has been done in two steps with the software Meteonorm, using (generated) hourly values for global horizontal irradiation. First, the average hourly global horizontal irradiation values are differentiated into direct and diffuse components by using the Perez et al. (1991) model. In a second step, the irradiation on an inclined surface is calculated with the help of these components. For this, another model of Perez (1986) is used. This second model also includes the effect of the raised skyline.

Details are described in "*http://www.meteonorm.com/media/pdf/mn6_theory.pdf* ".

	Ta	Global horizontal	Global tilted at 30°	Global tilted at 30° (NASA)
	[°C]	[kWh/m^2]	[kWh/m^2]	[kWh/m^2]
January	7.9	140	213	192
February	12.3	145	194	186
March	17.9	186	212	218
April	24	204	208	201
May	26.8	213	194	186
June	26.3	175	153	150
July	24.1	149	135	132
August	23.5	147	141	140
September	22.6	146	156	143
October	19.8	163	202	193
November	14.9	142	201	200
December	9.9	140	216	195
Year	**19.2**	**1952**	**2224**	**2136**

Table 4-4: Tilted at 30° global solar irradiation [kWh/m²/year] for Kathmandu.

With a 30° tilted angle, a solar PV module receives a global irradiation of 2'224 [kWh/m²/year], which corresponds to 12% increase in comparison with the same solar PV module mounted on an horizontal plan.

Global In-plane (tilt 30°, fixed, South oriented) Irradiation ≅ 2200 [kWh/m^2/year]

According to the graph below, the intercepted irradiation on a flat plate tilted at Kathmandu's latitude (27.5° North) is between 2010 and 2090 [kWh/m^2/year]. For purposes of comparison, the global horizontal solar irradiation in Munich, Germany, is only 1145 [kWh/m²] and the tilted annual (30°) solar irradiation reaches 1279 [kWh/m²], a figure 1000 [kWh/m²] lower than the value in Kathmandu.

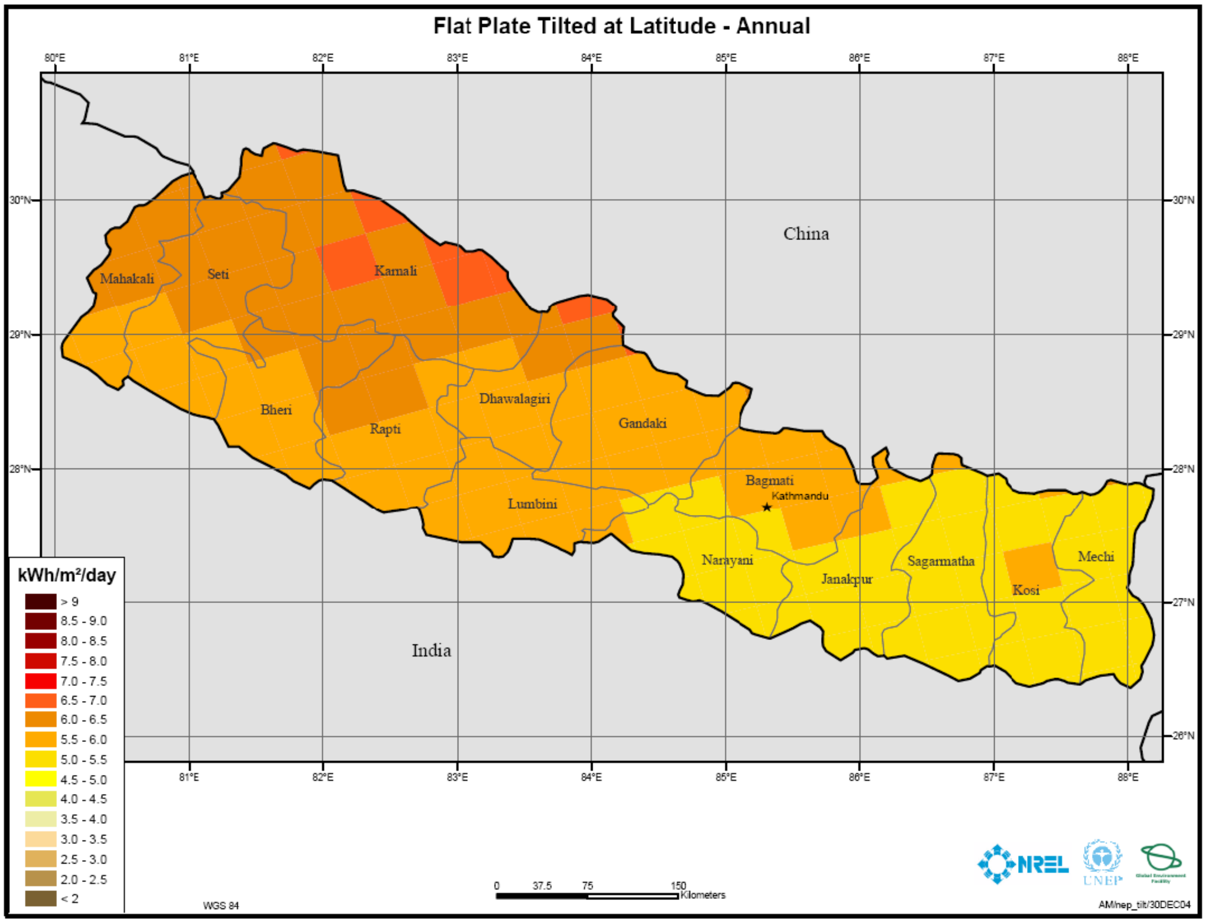


Figure 4-4: Tilted at latitude solar irradiation [kWh/m²/day] for Nepal.

The cost of energy produced by a PV plant installed in Nepal will consequently be proportionally smaller to the cost of energy produced by a similar installation in Europe.

Two-axis global monthly solar irradiation in Kathmandu:

In countries such as Nepal the use of two-axis trackers can be interesting, due to the favorable climatic and solar irradiation conditions. For the Kathmandu region, calculations (with PVSYST program) show that an annual global irradiation on a flat surface situated on a two axis-tracking system structure of 2937 [kWh/m^2] can be intercepted. That corresponds to an increase of 33.6% compared with the irradiation on a horizontal plan and an increase of 24 % compared with a fix 30° tilted plan.

Global In-plane (two-axis tracking) Irradiation ≅ 2940 [kWh/m^2/year]

Incident irradiation distribution:

The daily global irradiance distribution over the year is not constant and varies according to local climatic conditions. In countries with an important diffuse irradiation component (for example the UK), the number of hours at low irradiation is generally high. Consequently, the distribution of incident irradiation cannot be very significant with an irradiation peak (of energy) at low irradiance. In Nepal however, the diffuse component is lower, and, as it is shown in Figure 4-, incident irradiation is high at high irradiance.
This indicates that, for example, most of the produced energy will occur at a working point of the inverter in the upper part of the load curve.

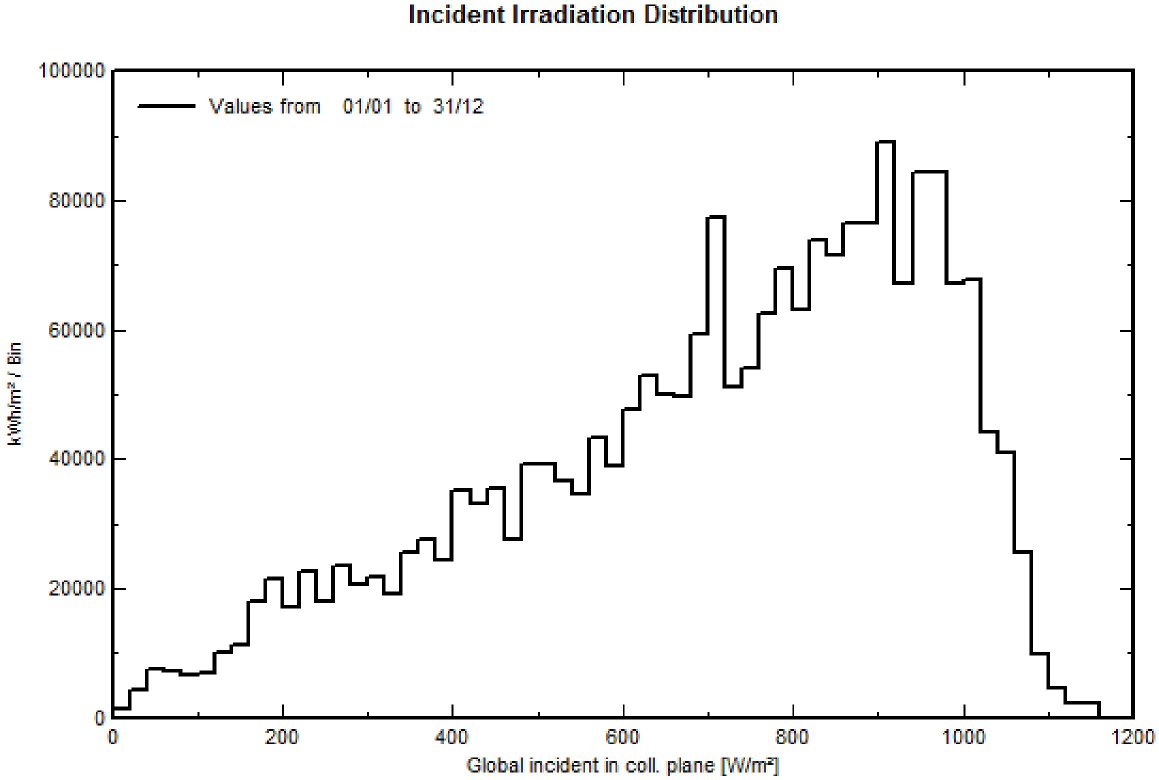


Figure 4-5: Incident irradiation distribution for a 30° tilted, South oriented, fixed plan in Nepal.

4.1.5 Altimetric Data

The current electricity grid network covers mainly the Kathmandu valley, the Pokhara region, the Terai and the most important urban centres. The present study considers only the situation of urbanized areas of the Kathmandu valley, where the mountainous horizon does not need to be considered as a possible source of shadow on PV plants. All calculations and simulations in the present document are carried out without considering close obstacles that could generate shadow, because these have to be taken into account on the basis of the particular, local characteristics of a plant. The positioning of a PV array on rooftops (or elsewhere) should in any case be chosen in order to avoid by every possible means any form of shadow (even partial) upon it. Concerning the effect of altitude on total solar irradiance, it has been demonstrated that there is an increase of total solar irradiance with altitude of about 8 % ± 2 % per 1000 m of Δh (Blumthaler, Ambach, & Ellinger, 1996).

4.1.6 Quality of Air

In the case of Kathmandu valley, and particularly in the city itself, the effect of air pollution and the presence of dust and seasonal mist substantially reduce the effective irradiation received on PV modules: the diffused irradiation increases and the direct irradiation decreases, with a global reduction of irradiation estimated around -15 % (this value has been approached through periodical measurements on standalone PV plants) (Zahnd A. , 2008). Substantial reduction of air pollution and dust would thus increase the productivity of PV systems in Kathmandu, but in any case it is of great importance to regularly clean the modules' surfaces in order to remove the dust (at least weekly).

4.2 Professional sector

The possibility of building grid-connected plants extensively depends on the Nepalese professional sector's capacity to provide the necessary competences and on the responsiveness of PV component purchase and distribution channels.
The next section provides analysis of the market survey carried out in April 2009 with today's main distributors of photovoltaic components.

4.2.1 Modules

In Nepal, 59 companies sell photovoltaic modules. Only 26 of these are approved by the AEPC, and therefore have access to GON subsidies for SHS.

The survey carried out for this study involved 23 out of the 26 companies in Kathmandu approved by the AEPC.
Last year's sales added up to **44'245 modules**; 4 companies did not provide information.
In catalogue, **220** module sizes from 11 manufacturers (Kyocera, Solarland, Sharp, Kaneka, Solarworld, Suntechnics, Moserbaer, TATA BP, Isophoton, Primier Solar, Mitsubishi) were available.
The mean power of the stated modules was 49Wp, but considering that the average sold power is about 30-32 W/module, the total amount of the Nepalese PV market reached **1.4MW in 2008** (Private companies, Telecom, Military).

Currently, the market provides mostly standalone applications for medium-small power plants. Consequently, the most commonly sold modules are of small size, under 50W. They are typically composed of 36 cells. The modules' quality is not always good, but can be considered generally acceptable, except for low-cost units imported from China and India. There still lacks a market for 60 cell modules, the most common size around the world. Only few 72 cell modules (24V system in standalone PV system) are to be found.
Importers perceive 60 cell modules as having a higher cost, however no feedback can be found to justify this perception.

Modules used in systems that receive grants must be tested and approved by the RETS. Modules that do not get the RETS approval do not even benefit from the VAT reduction from 13% to 2.5%.
Tests consist of measurements of the outdoor I-V characteristic, with extrapolation of data at STC (Standard Test Condition: Irradiance = 1000W/m2, cell temperature = 25°C, spectrum corresponding to air mass = AM1.5).

At the RETS, 119 modules ranging from 10 to 210Wp were validated between 2006 and 2009. Their mean power was 66.7W. 87 modules received approval and were accepted for grants.
Only 7 manufacturers of these modules were European (Germany and Spain), 29 came from India, 24 from Japan and 23 from China.

A gradual increase in the power of the modules found on the Nepalese PV market has been observed. However, the import channels are scarce, and module import is often complex. At present, modules are mainly imported from India, but Chinese import is growing.

Survey on EU, World, price for grid-connected modules (60 cells or other)

Module costs represent roughly 50- 60 % of the total cost of a grid-connected PV system. Therefore, the price of solar modules is the key element to determine the total price of an installed solar system. All prices reported in the present document exclude sales taxes.
In Nepal, the VAT tax for normal components is 16%. If a module is approved by RETS, it can be imported with a 2.5% VAT.

During 2009, the price of photovoltaic modules on the world market significantly decreased. Therefore, after the survey period, module prices continued to decrease. (**Errore. L'origine riferimento non è stata trovata.**).

The average cost per watt at the time of the survey (April 2009) was 351 NRs/W (3.25 €/Wp), but in November 2009, it had already decreased to approx 292 NRs/W (2.7€/Wp).

World module production is nowadays mostly dedicated to the realization of grid-connected systems. Module typologies with 36 or multiples of 36 cells are no longer necessary for grid-connected installation. Most producers provide 60 cell modules. Differences in cost between the world and the Nepalese markets are due to the limitations of the latter to SHS and to small power systems. The Nepalese market is therefore still relatively closed.

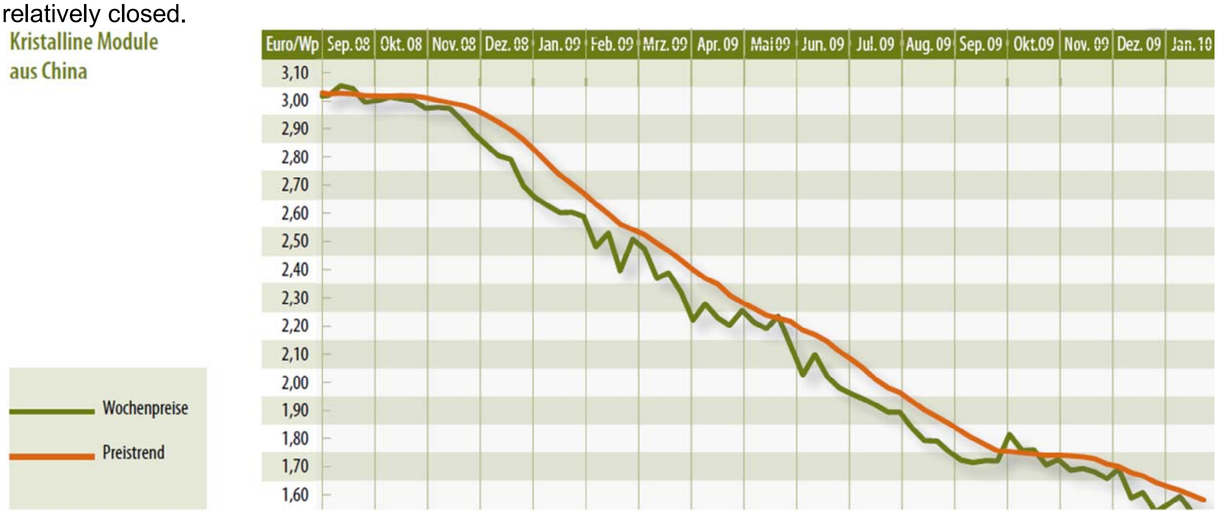


Figure 4-6: Weekly price trends of a Chinese crystalline silicon module in Euro/Wp.

Source: http://www.pvxchange.com/en/index.php/preisindex_3.html

A further information source about European and US price index is www.solarbuzz.com

4.2.2 Inverters for grid connection

An inverter used for connecting PV systems to the public grid has different distinctive characteristics when compared to the standalone inverters commonly used in Nepalese homes.
In Nepal, inverters for standalone systems are very common. They are coupled with a battery charger (where the grid exists) or with a PV module (where the grid is not accessible). They are used for times during which the grid is not available due to load shedding or unforeseen power shortages.
Hence, the market for grid-connected inverters (for PV systems intended to feed the generated power into the grid) is still open. Below are some of the necessary characteristics as well as practical evaluations for dimensioning grid-connected inverters. It should be noted that grid-connected inverters have to fulfill both the following legal and technical characteristics.
Legal characteristics:

1. Synchronous operation with the grid (≠ standalone inverter)
2. Islanding prevention, (≠ standalone inverter).
3. Limitation of the output voltage (min & max).
4. Limits of the grid frequency (49Hz < f < 51Hz, depending on the country)
5. Low phase displacement ($\cos\varphi \rightarrow 1$).
6. Low levels of harmonics. (≤ 3 % distortion).
7. Electromagnetic compatibility (EMC).
8. Eventually galvanic separation (trafo)

Technical characteristics:

1. High efficiency (η)
2. Power suitable for the field (Pdc and position)
3. Max Input Voltage
4. Overload capability (power limitation in case of P>Pmax))
5. Algorithm used for the adjustment of the MPP (Maximum Power Point)
6. High static and dynamic performance of the MPPT (η_{MPPT})
7. Reliability (and guarantee: 1-3 years; or better 5 years)
8. Automatic connection and disconnection
9. Minimum Power threshold of insertion
10. Insensitivity to the control signals of the grid.
11. Wide operating temperature
12. Size and weight
13. Price
14. Service / maintenance
15. Noise emissions
16. Measuring and/or monitoring system

It is not necessary that grid-connected PV inverters be able to withstand higher power conditions as is the case for standalone inverters, since grid-connected PV plants rarely produce much more power than at standard conditions. For the dimensioning calculation, the power of the inverter has to be determined so that the power of the plant does not excessively exceed the top ceiling in all the local climatic conditions.
(typically Pn of the module ≤ 120% of Pdc)

Technically, it is possible to change the connection parameters (voltage limits, frequency, etc.) during the importation phase or during installation.

Typical factors configuration in a setup that can vary according to local conditions and standards:

- Maximum AC output / maximum AC current
- Minimum mains voltage / maximum mains voltage
- Minimum mains frequency / maximum mains frequency
- Maximum frequency change per second / ENS setting
- Maximum fault current / maximum DC ratio in the AC current
- Start delay

In every region, grid-inverter settings must comply with the local standards.

Typically, grid inverters comply with the following standards:

EMC – Emission:	EN 61000-6-3: 2002-08
EMC – Immunity:	EN 61000-6-1: 2002-08
EMC – Harmonic current emissions :	EN 6100-3-2 : 2001-12
	EN 6100-3-3 : 2002-05
Equipment safety:	En 50178 : 1998-04

Frequency and voltage correspond to inverters of the main world market (meaning the European market). It is therefore normally possible to link all types of inverters to the Nepalese grid as long as legal adjustments are previously applied.

Parameter	Unit	Regional settings						Password-protected setting
		DE/CH	IT	ES	FR	GR	Other	
Vac max	V	264	274	253	264	264	300	184…300
Vac min	V	184	186	196	196	184	184	
f max	Hz	50.2	50.3	51	50.5	50.5	55	45…55
f min	Hz	47.5	49.7	48	49.5	49.5	45	
df/dt max	Hz/s	NA	0 (Inactive)	NA	NA	NA	NA	0.1…1
Vac 10min max	V	253	0 (Inactive)		264	0 (Inactive)	264	243…264
Ierr max	mA	300	300	300	300	300	300	50…300
Iac mean max	A	1	0.5 % of Iac rated*	1	1	0.5% of Iac rated*	1	0.05...1
Restart delay	s	0	0	180	0	180	0	0…600
Pac max SM2000S	W	1980	1980	1980	1980	1980	1980	990…1980
Pac max SM3000S	W	2750	2750	2750	2750	2750	2750	1375…2750
Pac max SM4200S	W	4180	4180	4180	4180	4180	4180	2090…4180
Pac max SM6000S	W	5060	5060	5060	5060	5060	5060	2530…5060
Iac max SM2000S	A	12	12	12	12	12	12	6…12
Iac max SM3000S	A	12	12	12	12	12	12	6…12
Iac max SM4200S	A	19	19	19	19	19	19	9…19
Iac max SM6000S	A	22	22	22	22	12	22	11…22

NA: not available * Iac max = 1.1 x Iac rated

Table 4-4: Example of configurable limit values and operational settings of a SOLARMAX inverter

European Efficiency:

One parameter given by manufacturers of PV inverters is the “European weighted efficiency”. It depends on yearly energy produced at different irradiances and is defined as:

$$\eta_{EU} = 0.03 * \eta_5 + 0.06 * \eta_{10} + 0.13 * \eta_{20} + 0.1 * \eta_{30} + 0.48 * \eta_{50} + 0.2 * \eta_{100}$$

Where:

- η_5 is the efficiency at 5% of nominal power.
- η_{10} is the efficiency at 10% of nominal power.
- Etc.

The European weighted efficiency is defined for areas of **northern Europe Alpine** climates (or higher than 40-45° Northern Latitude) – see example in Figure 4-.

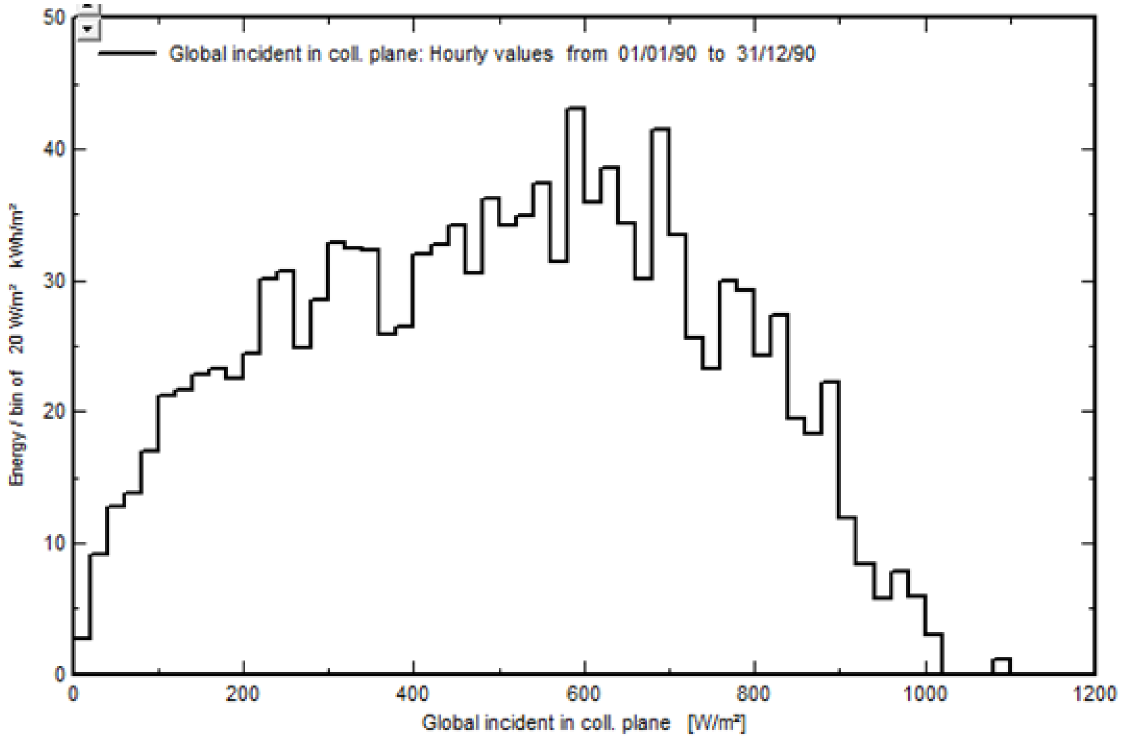


Figure 4-7: Example of incident irradiation distribution for a 30° tilted, South oriented, fixed plan in München (Germany)

In order to calculate the appropriate inverter weighted efficiency for **Nepal**, it is necessary to know the yearly energy produced at different irradiances and measured at 1 minute intervals. At the moment we do not have access to incident irradiation distribution data on a minute basis. However, it is possible to estimate it by using hourly values generated by stochastic simulation programs. However, these results normally reflect a normalized weight that is higher at low irradiance.

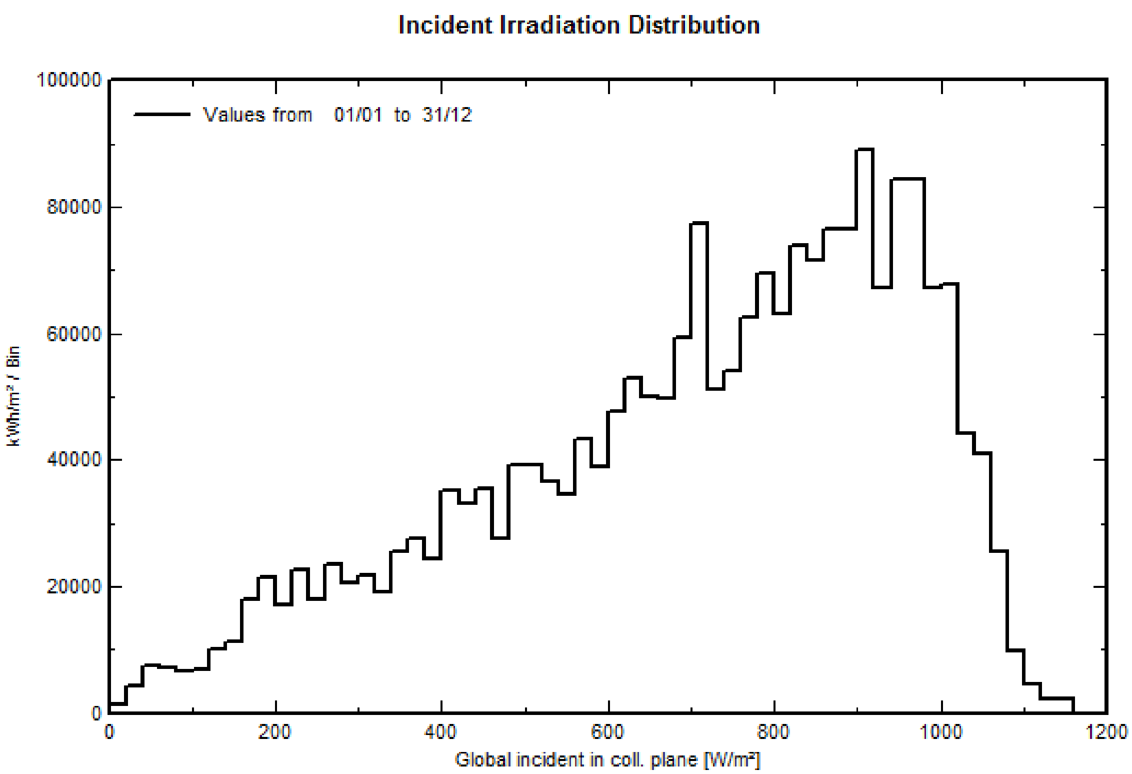


Figure 4-8: Incident irradiation distribution for a 30° tilted, South oriented, fixed plan in Nepal.

The incident irradiation distribution of Nepal is strongly shifted towards the higher irradiance values.

For the hourly data of incident Irradiation distribution, the "Nepalese weighted efficiency" can be approximated:

Nepalese inverter weighted efficiency:

$$\eta_{NS} = 0.05*\eta_{10} + 0.13*\eta_{30} + 0.22*\eta_{50} + 0.53*\eta_{90} + 0.07*\eta_{105}$$

Weighted efficiency is obtained by calculating the incident energy on the surface of the PV modules in various ranges of irradiation, and then by calculating the ratio with global incident energy.
It should be noted that the distribution of irradiation is strongly shifted towards the higher daily irradiance range (Figure 4-5 & 4-7, chap. 4.1.4 & 4.2.2). Therefore, compared to the European irradiation conditions, it is advisable to choose an inverter with a high efficiency at high power.

Currently, there is no market for grid-connected PV inverters in Nepal. However, they can be purchased through Indian and Chinese market.

4.2.3 Batteries

In a standard grid-connected system, a back-up battery is not necessary. A storage system is however required when the grid is unavailable for a significant amount of hours each day. In Nepal, in most of the country, the grid is unavailable for 2 to 16 hours per day, depending on the season. One of the most popular methods of solving this inconvenience in households is the use of batteries associated with an inverter.
In the survey conducted with PV modules sellers mentioned in chapter 4.2.1, the availability, price and type of batteries sold by the participants was also investigated. 22 sellers completed the feedback form.

In April 2009, the mean price per Ah of battery capacity was **117 NRs/Ah (1.07 €/Ah)**. In November 2009, the mean price per Ah had decreased to **108 NRs/Ah (0.99 €/Ah).**

Only five battery manufacturers were mentioned by sellers:
- Sunera (Kulayan, Nepal), flooded lead-acid, flat plate and tubular batteries
- Volta MX (Korea), flooded lead-acid, flat plate batteries
- Volta (Rahimfrooz, Bangladesh), flooded lead-acid, flat plate and tubular batteries
- Atlas (Korea)
- Unikor (China)

4.2.4 BOS: Balance of System

Mounting structures:

All solar companies use painted iron strips, angles and galvanised iron structures. They are all common and similar. Prices are usually almost identical for same-sized modules. All of them are manufactured and galvanised locally.

Figure 4-9: Mounting structures: a painted iron strip for 12-21Wp modules.

Figure 4-40: Mounting structures manufacturer who manufactures for most of the PV companies.

Energy meters:

Energy meters are available at ca. 600-800NRs.

Figure 4-51: Energy meter

Cables:
Like mounting structures, all the companies use locally manufactured cables. Trishakti Cables, Pioneer Cables, Nepal Cables, Prakash Cables, Janata Cables etc. are the main cable manufacturers and suppliers in Nepal. They produce all types of cable according to consumers needs (UV resistive cables, DC cables and AC cables). Prices are similar from one constructor to the other.

Trained staff with DC current knowledge:
Most companies did not want to provide any information about staff and qualifications. No further study has therefore been carried out.
The cost of trained staff (level I or level II) per month ranges between 8'000 NRs to 35'000 NRs.

4.2.5 Educational

In general, appropriate knowhow and professional skills are either very limited or simply not available in Nepalese PV companies. There is a great need for professionals with better training and education, especially among dealers and installers.

Only CES/TU and AEPC/ESAP, in association with SEMAN, have conducted various training programmes related to PV, such as the "Solar Electric Technicians Level-I Training" (Mandatory course for the installation of Solar Home Systems), "Solar Electric Technician Level–II" (designed for repair & maintenance), and "Training of Trainers (ToT) for Solar Electric Technicians". A "Training Manual for Engineers on Solar PV Systems" has been published (AEPC, 2008).

Until January 2009, 2043 participants (of which 56 female) have graduated at level 1, and 134 (of which 5 female) at level 2. The level 3 programme has not yet been offered. Currently, another 200 candidates wish to follow the courses. These training programmes award participants a certificate that is required to obtain subsidies for the installation solar PV plants.

At CES/TU, approx. 100 engineers have followed the course on PV technology so far (75 hours course). Half of them are now staying abroad for further education. In KTM there is no other specific educational programme on PV technology.

At KU, since 2004, 200 students have taken the one-semester "Renewable Energy" Bachelor course during the 4th year of their Mech. Engineering degree. This course includes an extended chapter on solar PV systems, their design and installation.
There is no specific professional training or course for grid-connected PV systems.
In the framework of this project, SUPSI, along with TU and KU/RIDS-Nepal have organized and held the first two training courses with an emphasis on grid-connected PV systems. Approx. 30 students coming from both of the partner universities have participated.

4.2.6 Installation control and standard for grid-connected PV Systems

When this report was submitted, there was still no technical standard dedicated to the grid-connected PV System available in Nepal.
In the past years a quality standard for standalone system was set up (NEPQA).

This technical standard for components of a solar photovoltaic (PV) system, called Nepal Photovoltaic Quality Assurance (NEPQA), was first developed and adopted by the Alternative Energy Promotion Centre/Energy Sector Assistance Programme (AEPC/ESAP) in December 2000 for dissemination of SHS under the ESAP.
The interim standard was needed because of the lack of a Nepal Standard (NS) for components used in PV systems. It was revised for the first time in Nov 2002 and for the second time in September 2005. The third revision is currently in vigor. The AEPC/ESAP uses the NEPQA standard to test Solar Home System (SHS) components at the Renewable Energy Test Station (RETS).
The RETS was established thanks to an investment and technical assistance from the AEPC/ESAP and hosted by Nepal Academy for Science & Technology (NAST). The Nepal Bureau of Standard & Metrology (NBSM) and The Solar Electric Manufacturers' Association Nepal (SEMAN) are the other two promoters of RETS. NEPQA provides the specification of the technical requirements of components used in Solar Home System (SHS).
The Renewable Energy Test Station (RETS) will test components based on this document. NEPQA has two categories of parameters. The first category includes the mandatory parameters for compliance and the second category includes recommendations. The recommended parameters are primarily intended for quality enhancement through product development. The RETS conducts two types of tests: The Product Introduction Test (PIT) and the Random Sampling Test (RST). The Product Introduction Test is carried out for introducing an SHS component for the first time under the subsidy programme. It is carried out before importing or locally manufacturing a component in bulk quantity. The company provides a few sample components to the RETS for testing. AEPC allows companies to import under VAT and import tax exemption conditions only components which pass the "Product Introduction Test". A "Random Sampling Test" is carried out, in general, at least once a year by the RETS for each component. The RETS technicians visit importers or manufacturers of components and PQ solar companies, and collect samples from a batch of components for testing at the RETS. Before components are used in subsidy programmes, they must pass the Product Introduction Test and the Random Sampling Test.

5 Institutional setup and legal basis

Since electricity is the main source of modern energy and is one of the drivers for rapid economic growth and poverty alleviation, the government of Nepal has set a target to increase the country's capacity by 10,000 MW in the next ten years. Meeting the target of adding thousands of megawatts of power within a short period of time is not an easy task, and requires the expansion of reliable transmission and distribution networks. Consequently, the issue of energy efficiency and conservation will need the full attention of the state, which is responsible for providing the institutional and legal framework as well as encouraging local competition with appropriate regulatory interventions.

5.1 Organization of the energy sector in Nepal

Currently, allocation of responsibilities with regards to the development and management of different sources of energy is spread over several recently constituted ministries and agencies (June 2009), such as the Ministry of Energy, the Ministry of Irrigation, the Ministry of Environment, the Ministry of Science and Technology, the Ministry of Forest and Soil Conservation, the Ministry of Agriculture and Cooperatives, the Ministry of Trade and Supplies and local government bodies. The Ministries deal with their own areas of operation and therefore, policies are not always consistent, and opportunities for inter-linkages and synergies tend to miss. The following chart represents the Ministries and bodies active in the energy sector in Nepal:

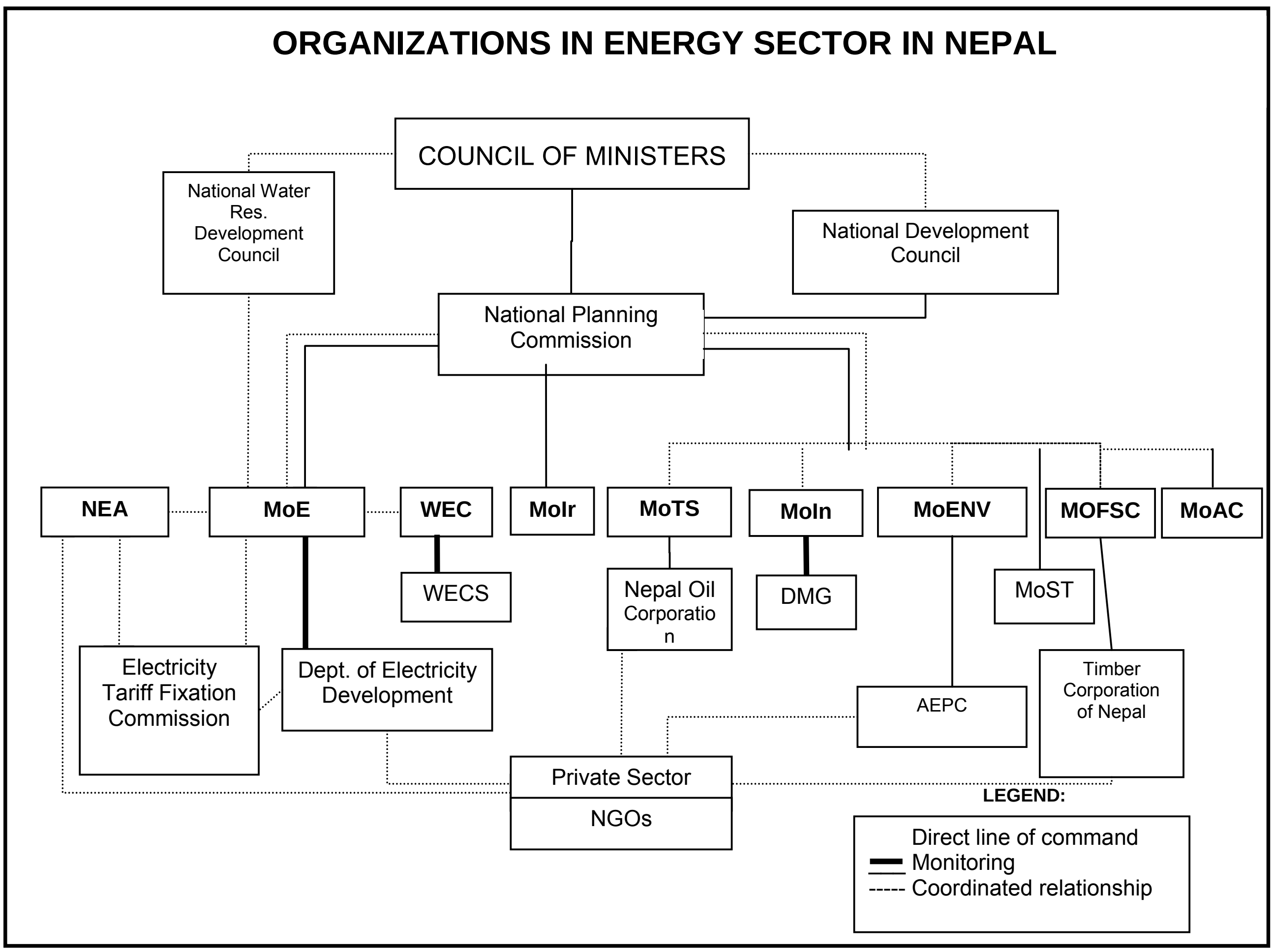


Figure 5-1: Organization chart of the energy sector in Nepal in 2009.

5.1.1 National Water Resources Development Council

The NWRDC, chaired by the Prime Minister, is the high level water resources policy institution formed in 1993. The membership of the Council is broad-based, with representatives from political parties including leaders of the opposition parties and people from outside the Government. It is a political forum for discussion on national issues related to water resources, with a view to building a national consensus for its development. The Council is mandated to:

- Contribute to the creation of a congenial environment for national consensus on the development and utilization of water resources to suit the development needs of the country.
- Decide on national water resources policy with a view to maximize the benefits of national interests.
- Determine policy foundations necessary for rapid and sustainable development of water resources.
- Identify the basis for coordination between various sectors and agencies.
- Issue directives to the government for enhancing national and international understanding on water resources development.

The NWRDC was formed after the serious national disagreement over the Tanakpur Agreement (December 6, 1991) between Nepal and India. Since the signing of the Mahakali Treaty (February 12, 1996) between the two countries for the integrated development of water resources on the Mahakali River, the NWRDC has remained dysfunctional.

5.1.2 National Planning Commission

The National Planning Commission, formed under the Transaction of Business Rules of the government, and chaired by the Prime Minister, is a central planning and coordination body, with jurisdiction over all ministries and public sector agencies to formulate periodic and annual plans and supervise their implementation.

The NPC functions under the broad directives and guidelines given by the National Development Council. The main functions of NPC are to:

- Formulate periodic plans on the basis of the long-term goals and guidelines of the NDC.
- Issue directives to concerned ministries in connection with the formulation of national development plans.
- Collect data and conduct necessary research for the formulation of national development plans.
- Estimate internal and external resources required for financing annual and periodic plans.
- Monitor and evaluate development projects.

In general, NPC brings together all the sub-sectorial energy development plans and programmes, and includes them in the periodic national plan.

5.1.3 Water and Energy Commission

The Water and Energy Commission, established in 1975, is chaired by the Minister in charge of MoE (former Ministry of Water Resources), which was reconstituted in January 1999 with wider representation, including secretaries of eleven ministries and five other members from outside the government. The functions of the WEC are to:

- Develop the water and energy resources in an integrated and accelerated manner.
- Review and cause to review multipurpose, large and medium scale water resources projects and advise on their implementation.
- Formulate and cause to formulate policy and strategy to conduct studies, researches, surveys and analysis, with regard to various aspects of water resources and energy development, in accordance with priorities and aims of the government.
- Analyze and cause to analyze bilateral and multilateral projects relating to water resources development and energy, formulate policies in this respect, review and analyze such projects.
- Enact and cause to enact necessary laws pertaining to the development of water resources and energy.
- Establish and cause to establish coordination between national and sectorial policies relating to water resources and energy.

5.1.4 Water and Energy Commission Secretariat

The Water and Energy Commission Secretariat was established in 1981 under the Transaction of Business Rules of the government to provide technical and administrative support to the WEC and carry out a policy advisory function. The mandate of the WECS is to:

- Formulate necessary policies and strategies to conduct studies, researches, surveys and analysis on various aspects of water resources and energy development to follow the priorities and targets of GoN.

- Enact the necessary laws pertaining to the development of water resources and energy.
- Establish coordination among national and sectorial policies relating to water resources and the energy sector.
- Identify the viable power projects and make an analysis of bilateral and multilateral projects relating to the development of water resources and energy.
- Conduct the study of national electricity demand, forecast and system planning.

The WECS has prepared, published and distributed technical reports on water, energy, environmental, legal and social issues. It has also provided technical input at various levels in the preparation of policy, development of sectorial master plans, guidelines, various water and energy related laws and policies. The WEC/WECS have also received strategic planning mandates for the whole water and energy sectors.

5.1.5 Nepal Electricity Authority

The NEA was established under the Nepal Electricity Authority Act, 1984, and is primarily responsible for the planning, construction and operations concerning electric supply. Its major function comprises electricity generation, transmission and distribution, but it has no legal authority to formulate its own policies. Presently, there are various Independent Power Producers who generate electricity, and who, under Power Purchase Agreement with the NEA, sell bulk power to the NEA. The NEA is also in the process of unbundling (separation of generation, transmission and distribution), as envisaged by the National Water Plan (2005). The GoN, through the NEA, executes rural electrification programmes. It has started to promote public participation so as to reduce theft, thus bringing effectiveness to the present distribution arrangement by conducting maintenance and distribution systems on a community basis, through the Distributing Institution.

As far as generation is concerned, the NEA has been facing the serious problem of inadequacy in the supply because of i) decrease in water supply in rivers during dry seasons, and ii) increasing demand for electricity. Despite having the monopoly over the transmission and distribution of electricity on the national grid, the NEA also faces significant problems with respect to these functions. The low capacity of the Hetauda-Bardaghat 132 KV transmission line and the very lengthy eastern (Butwal-Anarmani) section of the national grid have prevented any regular and reliable supply in electricity. As far as distribution is concerned, the NEA has been incurring a total leakage of 24.7% of supplied electricity. Of that figure, 6% can be attributed to technical inefficiencies in the transmission line, while the remaining 18.7% are due to losses in the distribution system attributable to social (power theft) and security reasons. According to (NEA, 2009), the total leakage loss in 2009 reached 26% of the total energy generation.

5.1.6 Ministry of Energy (Formerly Ministry of Water Resources)

The MoE is responsible for formulation of policies and plans for the development, management and conservation of electrical energy resources; for the promotion, construction, operation and maintenance of multipurpose projects; for the development of human resources; for the promotion of the private sector in the development of electric power; and for negotiating and concluding bilateral and multilateral agreements concerning the utilization of energy (electrical) resources. At the policy level, the Ministry of Energy is responsible for energy resources as well as international and multi-purpose use aspects of energy resources.

5.1.7 Department of Electricity Development

The DOED is a policy implementation body of the Ministry of Energy. Its responsibilities are to:

- Conduct surveys, feasibility studies, and select hydropower projects in the country.
- Promote bilateral and multilateral large and medium sized projects.
- Prepare master plans of river basins.
- Promote and develop private sector participation in the development of electricity.
- Provide licenses and necessary facilities to private entrepreneurs.
- Prepare and inspect standards for electricity sector works.
- Assist the MoE in monitoring and evaluating electricity related development works.
- Function as Secretariat to the Electricity Tariff Fixation Commission.
- Conduct Power Development Funds formed by grants and loans from the World Bank.
- Study and develop heat, solar and wind energy.

In terms of the government's liberalization policy, there will be increasingly multiple stakeholders (public, private, community/cooperative and local government) in hydropower development. Therefore, the DOED, being the key central government agency, needs to ensure transparency of operation for all stakeholders. But the way licenses were given to the private entrepreneurs to develop certain significant hydro-power projects does not bode well for transparent level playing fields for all stakeholders. In addition, it should also be authorized to publish the national electricity status bi-annually (demand, supply, availability, generation, transmission, distribution, trade), so as to introduce a real-time, data-based monitoring mechanism for the enforcement of accountability by the competent authorities (the ministry, Parliament).

5.1.8 Electricity Tariff Fixation Commission

The ETFC was established separately under the Electricity Act (1992) to fix the tariff of electricity. The price structure for the electricity transmitted by the national grid and distributed by NEA is fixed by the Electricity Tariff Fixation Commission, while, in the isolated systems with alternative/renewable energy, the prices are fixed by the producer. For the last five years, the ETFC has not been able to adjust the electricity tariff despite repeated requests by the NEA. Currently, the DOED is the regulator for safety and technical issues, and the ETFC is the regulator for tariff issues. There is an ongoing act to establish the Electricity Regulation Commission as the unique body that will be responsible for all technical end tariffs regulation.

5.1.9 Ministry of Environment

The MoENV is responsible for the development of available, traditional technology and for the transfer of appropriate technology for the overall development of the country. Its major responsibilities include the formulation and implementation of policies, plans and programmes pertaining to the environment. It promotes activities for a sustainable environment as well as projects for the development of renewable energy in the country, and it stipulates environmental considerations to be respected by development projects/programmes that fall under the criteria set forth by the Environmental Protection Act and Environment Protection Rules. The MoENV also acts as the Designated National Authority for all Clean Development Mechanism (CDM) activities in Nepal.

The MoENV’s policy functions relate to pollution control; environmental conservation and balance; exploration and analysis of the achievements obtained in the field of technology; promotion of alternative energy; liaison and coordination with universities with regard to science and technology.

5.1.10 Alternative Energy Promotion Centre

The AEPC was formed in 1996, and is an autonomous government organization under the MoENV. It promotes the use of alternative and renewable energy in rural areas, facilitates their implementation and organises training programmes on various renewable energy technologies. Besides, the AEPC is active in coordinating the participation of the various donors in the field of renewable energy projects in the country. Micro-energy technologies supported by the AEPC programmes are: micro-hydro, biogas, Biomass (including improved cook stoves), solar (solar home system, solar dryer and cookers), mini-grid electrification, and wind energy. It is established under the Development Board Act 2013. The major functions of the AEPC are to:

- Supervise the execution of works;
- Disseminate and promote renewable energy technologies;
- Conduct studies and research on Rural Energy;
- Perform subsidy mobilization;
- Provide technical assistance;
- Select private companies and institutions for implementations;
- Co-ordinate with donor agencies;
- Perform monitoring and evaluations.

The AEPC works for off-grid alternative energy plants. The price structure of isolated systems along with micro-hydro generated electricity is fixed according to the generator. The electricity produced this way is categorized as isolated system or mini-grid due to localized electrification in the area.

Private companies and NGOs are involved in joint participation or under contract with the AEPC, or operate independently, particularly in providing manufacturing and installation or consulting services for the promotion of micro-renewable energy.

5.1.11 RETS, Renewable Energy Test Station

The RETS, formerly known as the “Solar Energy Test Station”, is an autonomous body governed by “RENEWABLE ENERGY TEST STATION RULES 2063”, under clause 31 of the Nepal Academy of Science, and Technology Act 2048. It is a centre for the assurance of quality in renewable energy, whose mission is to *“Contribute towards quality development and sustainable utility of renewable energy sector by providing quality testing and related services”* (RETS).

Though the RETS is contributing in an important way to the qualitative development of the PV sector in Nepal, it is observed by various stakeholders of the sector that it would benefit from more skilled manpower and better equipment. Also, it should provide test results within shorter time frames.

RETS conducts two type of tests: the Product Introduction Test (PIT) and the Random Sampling Test (RST). The Product Introduction Test is carried out for the initial introduction of a SHS component into the subsidy programme. It is carried out before importing or locally manufacturing components in bulk quantity. Companies provide a few sample components for testing at the RETS. AEPC will only allow the importation of components under VAT and import tax exemption conditions if they pass the Product Introduction Test. The Random Sampling Test is generally carried out at least once a year for each component by RETS. RETS technicians will visit Importers or Manufacturers of components and PQ solar companies, and collect samples of a lot of components for testing at RETS. Before components are used in subsidy programme, they must pass Product Introduction Test and Random Sampling Test.

PV modules are tested at real, ambient conditions. Outdoor measures are then extrapolated at STC (Standard test conditions: 1000W/m^2, 25°C, AM1.5). However, outdoor measures present a high measure of uncertainty, particularly if measured temperature coefficients are not applied for every specific module or standard values. With this view, amorphous silicon (a-Si) and micromorph (multi-junction a-Si/μc-Si) Thin Film modules would be particularly suitable for the Nepali climatic conditions (this is mainly true for the low altitude Terai conditions, where the ambient temperature is high as well as the diffuse ratio during the 3 months of rainy season. It is less applicable though for high altitude regions, where most of the year the beam radiation is high, and where mono and poly-crystalline modules are roughly twice as efficient, and thus half the size and weight, a determinant factor for installations in remote areas deprived of road access). When measuring the characteristics of these particular modules, it is essential to consider the degradation and regeneration cycles and therefore, to correctly define preconditioning conditions so as to stabilize power in a reproducible way. This cannot be achieved with the current equipment at the centre (something that needs to be developed). Indeed, nowadays, a-Si and multi-junction a-Si/μc-Si modules are practically absent of the market because of the difficulties in passing tests developed merely for crystalline silicon modules.

5.1.12 Legal context for Independent Private Producers

The NEA performs Power Purchase Agreements with the IPPs after completing the due procedures. The main procedures are the power evacuation study and the connection agreement. In fact, a PPA is a negotiation document which not only fixes the price of electricity, but also legally binds both parties (NEA and IPP) to thereafter operate as per the negotiation and commitment signed in the PPA. After the completion of the construction, the NEA performs a few mandatory tests on the plants and transmission systems.
During operation, the IPP is bound to supply the power and energy agreed upon in the PPA, and in the same manner, the NEA is obliged to purchase and transmit that same amount of power and energy. Not fulfilling the agreed conditions for supply and evacuation can be subjected to financial penalties. During the dry seasons, an IPP may reduce its committed power and energy to 90% with a prior notice to the NEA (usually with 15 days of anticipation). However, during the rainy season, the power and energy supplied can be reduced to 60% of the committed. Further reduction in supplied power and energy will lead the IPP to a financial penalty. The penalty is calculated as [0.8*(EC-ES)*EIP], where EC= Energy Committed, ES= Energy Supplied and EIP= Electricity Price. Similarly, if the NEA is unable to evacuate the agreed energy from the plant of the IPP, it has to pay for the produced electricity.
IPPs can perform scheduled maintenance as approved by the NEA. Any other shutdowns of the plants except for the *force majeure* mentioned in the PPA are also subjected to the penalties. Similarly, there is a provision of penalty for the NEA as well for its outages. However, for total annual outages of 216 hours in 11 kV and 144 hours in 33 kV, the NEA is exempted from this penalty.

5.1.13 Legal basis for grid fed technologies

The transmission network of the Nepalese power system has a highest voltage of 132 kV, while 220 kV transmission lines are under construction. IPPs are synchronized to the NEA network at different voltage levels. The transmission network uses hydro power as its major generation technology. However, there are a few fossil fuel powered thermal stations (diesel generators) based on petroleum. Almost all IPPs connected to the grid are based on hydro. However, the board of the NEA has taken decided to purchase power from two other types of alternative technologies: wind and biomass. This decision has simplified PPAs and other requirements regarding these technologies. Thanks to this decision, a PPA has been signed between NEA and an IPP for an installed capacity of 500 kW based on biomass technology. Power will be purchased from such technologies based upon the posted price of electricity.
Government of Nepal has opened the way for captive generation and co-generation. This can be seen as opening the way for oil thermal plants. Thus, the possible grid fed technologies so far are hydro, oil thermal,

biomass and wind power plants. If an IPP wants to sell electricity generated with other technologies, such as solar PV, a decision similar to that for biomass and wind must be made by the management board of NEA.

5.2 The national electricity grid

Nepal is a hydropower dominated system. The abundant hydropower generation possibilities have created the opportunity not only for the electrification of the whole nation, but also for a huge boost to the country's economy.
Main points:

- The total economically feasible potential for Hydro Power in Nepal is about **42,000 MW.** In comparison, only **about 636 MW** had been utilized until August 2009.
- During the fiscal year 2008/2009, the total annual energy generated by (government owned) Nepal Electricity Authority's (NEA) 17 major hydro power plants (424.12 MW) and the two thermal, diesel power plants (53.4 MW) was 1841.636 GWh[i]. Additionally, the 26% energy loss due to transmission and theft, as mentioned above, has to be considered, limiting the available energy for consumers to 1363.811 GWh. This amounts to a capacity factor of only 32.6% of the available installed power generation facilities.
- Furthermore, this shows that the installed capacity represents only **1.6 %** of the economically feasible hydro power generation of Nepal, a figure further diminished to <0.5% if the power plants poor capacity factors and the high transmission losses are included. .
- This production doesn't supply enough power to support the total load peak demand, about **850 MW** in 2009.
- To satisfy this load demand, an increase of about **50%** in hydro power or other sources is required to complete national electrification.

5.2.1 Power generation, transmission and distribution schemes

The Integrated Nepal Power System (INPS) disposes of 680 MW of installed capacity. The power system is dominated by hydropower, which contributes to about 90 % of the system. The other 10% include multi-fuel plants. Hydropower development in Nepal began with the development of the 500 kW Pharping power plant in 1911. The largest power plant constructed to this day is the 144-MW Kali Gandaki "A" Hydroelectric Plant. The latter started its commercial operation in August 2002. The most recent hydropower plant commissioned (December, 2008) is the 70MW Midddle-Marshyangdi Hydro Electric plant.
Until 1990, hydropower development was under the exclusive responsibility of the government, specifically of the Nepal Electricity Act (NEA). However, with the enactment of the new Hydropower Development Policy of 1992, Hydropower development has been opened to the private sector as well. There have already been numerous projects built by private developers. Indeed, the private power producers' contribution to the Integrated Nepal Power System (INPS) represents 158 MW.
The **generation scheme** is composed by 3 types of hydropower plants: Run of River (ROR), Peaking ROR (PROR), and Seasonal Storage (STO).
The existing hydropower plants with respective relevant information are listed in the following table:

S.N.	**Power Plant**	**Capacity (MW)**	**Year of commercial operation**	**Annual Energy (GWh)**	**Type**
1	Trishuli	24	1967	292	ROR
2	Sunkoshi	10	1972	66	ROR
3	Gandak	15	1978-79	53	ROR
4	Kulekhani I	60	1982	164	STO
5	Devighat	14	1984	13	ROR
6	Kulekhani II	32	1986	96	STO
7	Marshyangdi	69	1989	519	PROR
8	Puwakhola	6	2000	41	ROR
9	Modi	15	2000	87	ROR
10	Kaligandaki A	144	2002	791	PROR
11	Midddle-Marshyangdi	70	2009	398	PROR
	TOTAL	**459 MW**		**2520 GWh**	
	Small Hydro stations				
12	*Chatara*	*3.2*	*1996*		
13	*Panauti*	*2.4*	*1965*		
14	*Tatopani/ Myagdi*	*2*			
15	*Seti (pokhara)*	*1.5*	*1987*		
16	*Fewa (pokhara)*	*1.0*	*1967*		

17	*Tinau (Butwal)*	*1.024*			
18	*Sundarijal*	*0.64*			
19	*Farping*	*0.5*			
20	*Jomsom*	*0.24*			
21	*Baglung*	*0.2*			
22	*29 isolated small hydro power stations*	*5.676*	*Total capacity*		
	TOTAL	**18.38 MW**			

Table 5-1: Hydropower Plants in Operation Developed by NEA in August 2009

S.N.	Power Plant	Capacity (MW)	Year of commercial operation	Annual Energy (GWh)	Owned by	Type
1.	Andhikhola	5	1991	38	BPC	ROR
2.	Jhimruk	12	1994	81	BPC	ROR
3.	Khimti	60	2000	353	HPL	ROR
4.	Upper Bhotekoshi	36	2001	246	BKPC	ROR
5.	Indrawati	7.5	2002	51	NHPC	ROR
6.	Sange	0.18	2002	1.2	SHC	ROR
7.	Chilime	20	2003	101	CHC	PROR
8.	Piluwa	3	2003	18	AVHCO	ROR
9.	Rairang	0.5	2004	1.2	RHPD	ROR
10.	Sunkoshi Small	2.5	2005	14.5	SHPC	ROR
11.	Chaku Khola	1.5	2005	7.9	Alliance Power	ROR
12.	Khudi	3.45	2006	26.5	KHL	ROR
13.	Baramchi	0.98	2007	7.8	UHL	ROR
14.	Thoppalkhola	1.65	2008	3.3	THPC	ROR
15.	Phemekhola	0.995	2008	3.3	KHPC	ROR
16.	Sisnekhola	0.75	2008	3.1	GBHPL	ROR
17.	Salinadi	0.232	2008	0.35	KSHPL	ROR
18.	Microhydro	14.5				
	Total	**181.08 MW**		**957.15 GWh**		

Table 5-2: Hydropower Developed by IPP in August 2009.

In addition to these hydro power plants, there are two oil powered thermal plants owned by NEA: Multifuel (39 MW) and Hetauda Diesel (14.41 MW).

NEA also owns two isolated solar power stations, both funded and built by the French government in 1989:

1. Simikot (50kW). Lately, it produced DC power only (all the other functions are out of order). Between 2002-3 and 2008, its production was limited to about 1-3 hours a day of DC power for incandescent lights without switches. Since late 2008, the PV plant is no longer operative.
2. Gamgadi (50kW), which has no longer been operative since October 2006.

The total installed capacity of the NEA (including thermal power plants) is **530 MW,** while that of IPPs is **180 MW**. The total capacity of grid-connected power stations is **525 MW**. In addition to these, there are micro hydropower plants with a total capacity superior to **14MW**.

Transmission Schemes:

- Grid (INPS) extends from east to west, i.e., Anarmani- Mahendranagar
- Major hydropower stations connected to the grid.
- GSS Capacity: 1310 MVA
- 132 kV line length: 2076 cct Km
- 66 kV line length: 586 cct Km
- Main voltage of grid systems is 132 kV
- The majority of the lines are constructed with a double circuit
- Constructed with conductor BEAR and DUCK
- 220kV Khimti- Dhalkebar and 220kV Hetauda- Bharatpur under construction

The transmission network of the Integrated Nepal Power System (INPS) extends from east to west, i.e., Anarmani- Mahendranagar. The major hydro stations, as well as the two thermal stations, are connected to the grid. The principal voltage level of INPS is 132kV. The total length of 132kV transmission lines is 2076 km, the total for 66kV lines is 586 km. The total capacity of the grid substations is 1310 MVA. The majority of the lines are constructed with a double circuit (except for the Bardghat-Hetauda section), and most of them are constructed with BEAR and DUCK conductors (except for Bardghat-Hetauda and Bharatpur-Pokhara). Expansions in the transmission system are required to provide greater reliability and capacity, thereby increasing the ability to distribute available power and meet existing and future demands. Expansions are also necessary to meet the NEA's contractual transmission obligations with the various power producers, and to increase the NEA's capacity for import and export. The existing transmission lines with relevant information are listed below:

	132kV Transmission Lines	**Length (km)**	**Type of Ckts**
1.	Anarmani –Duhabi	85	Single
2.	Kusha-Kataiya (India)	19	Single
3.	Duhabi-Hetauda	282	Double
4.	Heatuda-KL2 P/S	8	Single
5.	Bharatpur-Marshyangdi P/S	25	Single
6.	Marshyangdi P/S- Siuchatar	84	Single
7.	Siuchatar- KL2 P/S	34	Single
8.	Siuchatar- New Bhaktapur	26.9	Single
9.	New Bhaktapur – Lamosangu	48	Double
10.	Lamosangu- Khimti	46	Single
11.	Hetauda –Gandak P/S	154	Single
12.	Bharatpur- Pokhara	97	Single
13.	Bardhaghat- Butwal	43	Double
14.	Butwal –KGA P/S	58	Double
15.	KGA P/S – Lekhnath	48	Single
16.	Pokhara- Modikhola P/S	37	Single
17.	Butwal Tanakpur P/S	407	Single
18.	Pathalaiya- New Parwanipur	17	Double
19.	Marsyangdi- Mid. Marshyangdi	44	Single
	Total	**1562.90 km**	

Table 5-3: 132kV Transmission Lines in August 2009.

	66kV Transmission Lines	**Length (km)**	**Type of Ckts**
1.	Chillime P/S- Devighat P/S	43.56	Single
2.	Trishuli P/S- Balaju	29	Double
3.	Devighat P/S – Balaju	30	Single
4.	Devighat P/S – New Chabel	33	Single
5.	Balaju- Lainchaur	2.3	Single
6.	Balaju- KL1 P/S	36	Double
7.	KL 1 P/S – Birgunj	72	Double
8.	Suichatar – Teku	4.1	Single
9.	Suichatar – New Patan	4	Double
10.	Teku –K3 (Underground)	3.5	Single
11.	Siuchatar- K3	6.9	Single
12.	New Patan- New Baneshwor	2.8	Single
13.	Bhaktapur- New Chabel	12	Single
14.	New Baneshwor- Sunkoshi P/S	61	Single
15.	Devighat- Trishuli	4.56	Single
16.	Indrawati – Panchkhal	10	Single
	Total	**354.72 km**	

Table 5-4: 66 kV Transmission Lines in August 2009.

There is a number of transmission lines under construction that include the highest voltage (220kV) links: 220kV Khimti- Dhalkebar (75 km, single) and Hetauda- Bharatpur (72 km, double). Other high voltage lines (132kV) under construction are: Thankot-Chapagaon (28.5km, double) and Chameliya- Attaria (129 km, single).

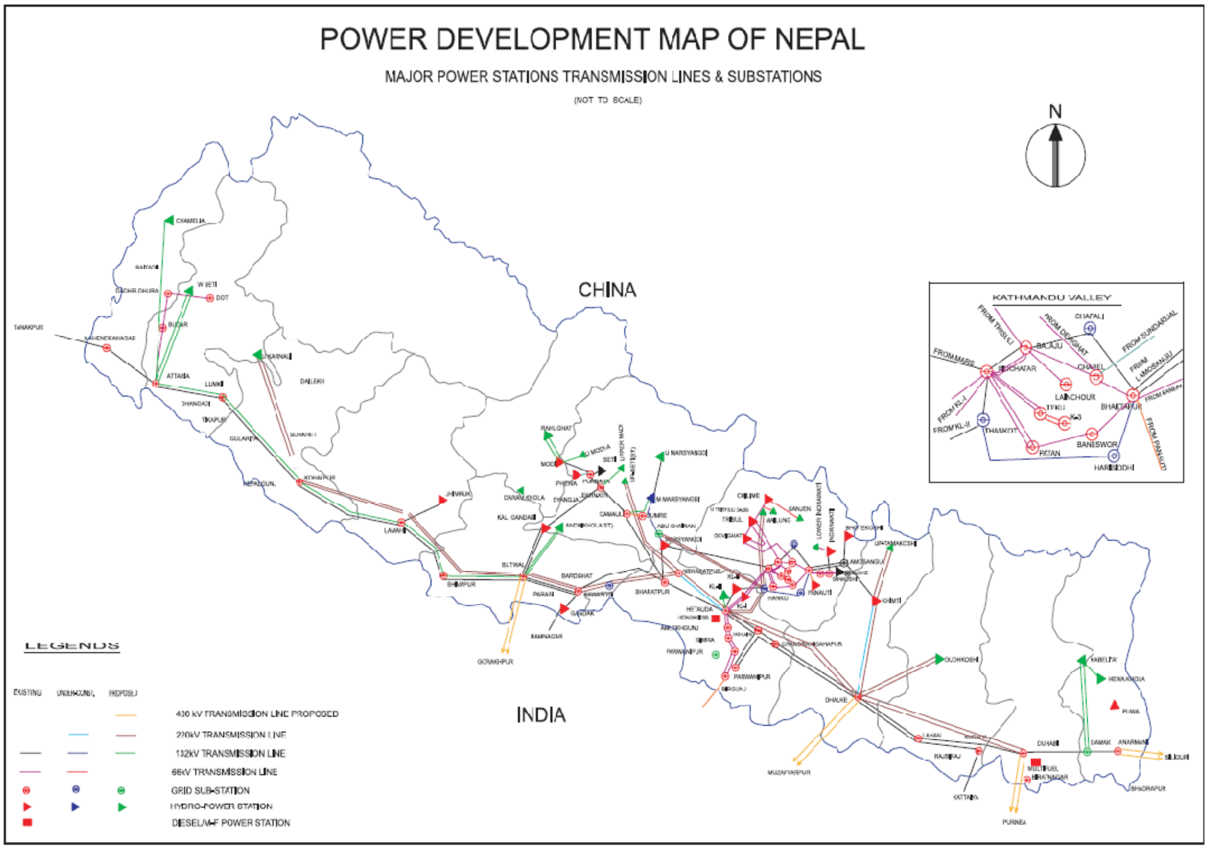


Figure 5-2 Major power stations and transmission lines and substations in Nepal in August 2009.

Distribution Schemes:

The distribution system is composed by a sub-transmission system at 33kV and a primary distribution system at 11kV. The secondary distribution is at 400/230 V. NEA owns and operates the distribution system.

5.2.2 Power peaking time

In Nepal, there are two peaks in the instant power consumption curve, during the days of both the dry and wet season. They happen early in the morning between 06:00 and 09:00, and during the evening between 16:00, and 19:00, and correspond to times of main household activities.

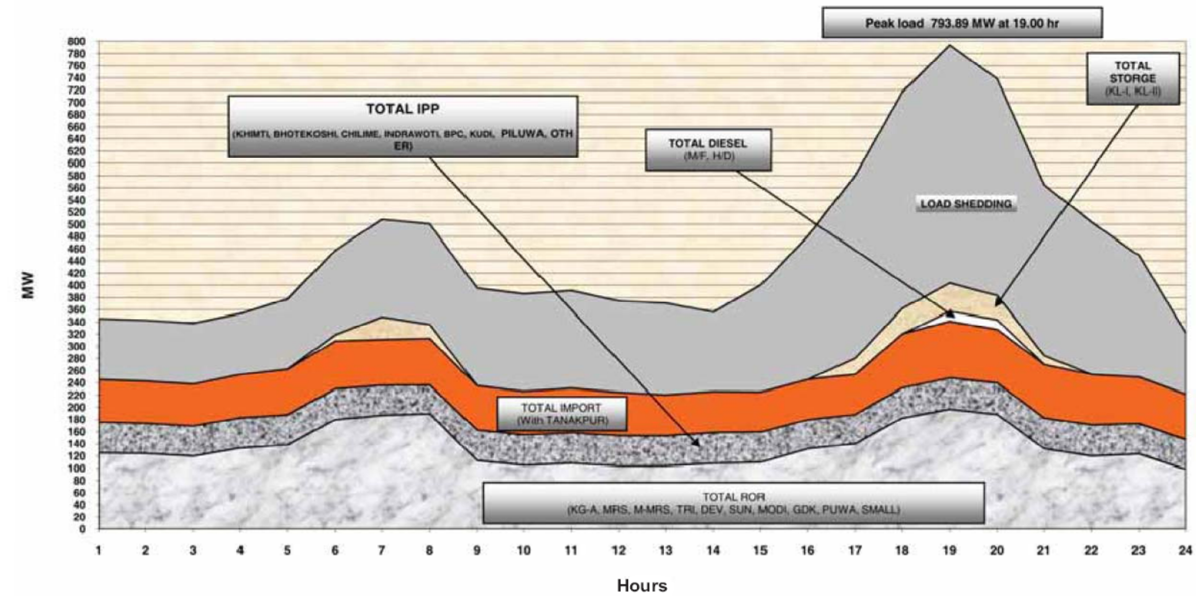


Figure 5-3: System load curve of typical dry season day (March 8, 2009), (source: NEA 2009 Annual Report).

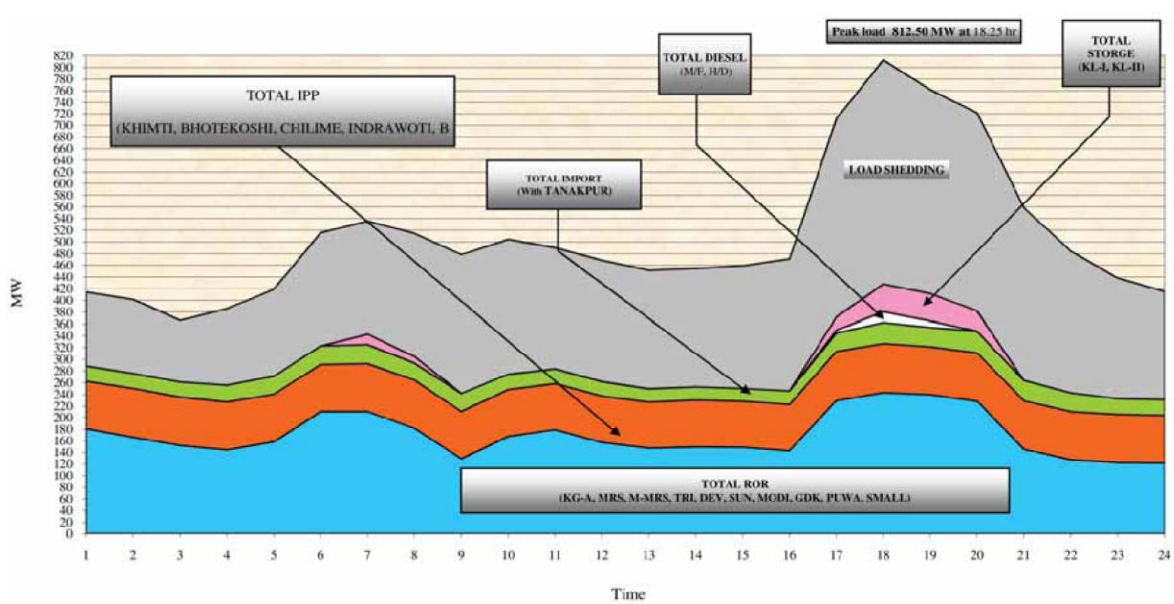


Figure 5-4: System load curve of the peak day of the year (January 20, 2009), (source NEA 2009 Annual Report).

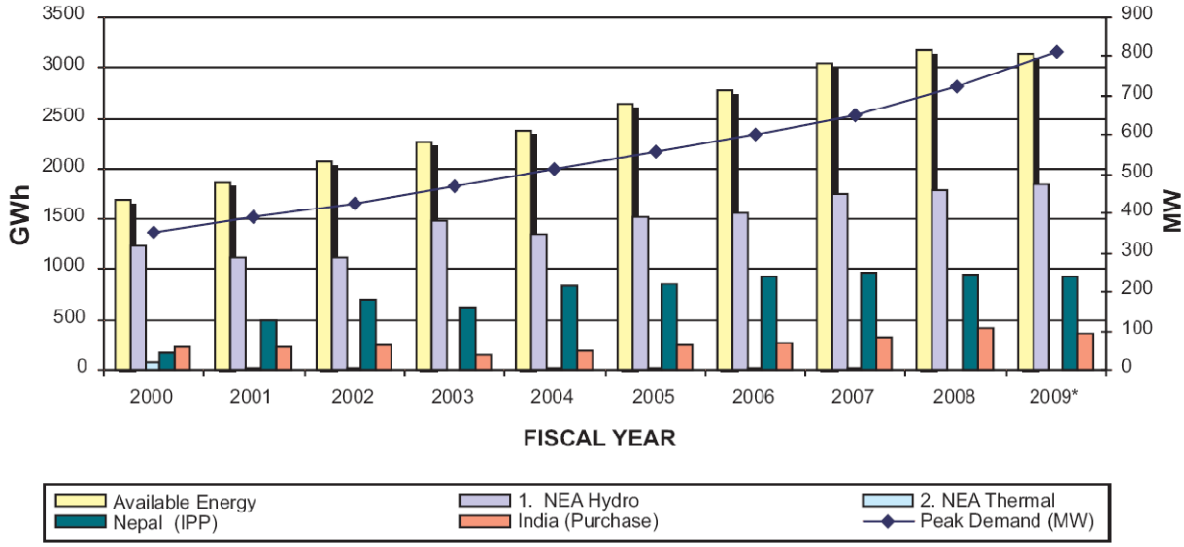


Figure 5-5: Total available energy and peak demand (source NEA 2009 Annual Report).

Peak demand is covered in all areas thanks to an integrated system that considers importation from India. However, in 2009, the peak load was close to the available energy, thus increasing load shedding.

It should be noted that the yearly annual demand is higher than the supply possibility. In order to stabilize the system, it is therefore necessary to limit the supply with a planned distribution to the various parts of the countries (see chapter 5.3.4).

5.2.3 Standards and norms

The NEA has set operational and construction standards in regards to transmission and distribution. The operational standards are mentioned in the Electricity Distribution Bylaws of NEA for the distribution, whereas the grid code has been introduced to regulate the operational and construction standards of the transmission system.

The NEA Grid **code of conduct for:**
- Grid Owner;
- System Operator;
- Grid Constructor;
- Generators;
- Distributors;
- Any other non-NEA entity with a User System connected to the Grid

The NEA electricity distribution bylaws, **code of conduct for:**
- Distributor
- Distribution System Constructor
- Consumers

5.2.4 Transmission and Distribution Losses and Stability

Grid Losses over time

Losses occur in a power system during generation, transmission and distribution. The power loss is broadly divided into technical and non-technical losses. Technical loss is due to the inherent properties of the power system components and is the aggregate of conductor loss, transformer loss and loss due to metering inaccuracy. Non-technical loss is the aggregate of energy loss due to meter-reading errors and tampering of energy meters and other measurement equipments. Electricity theft is a major cause of the non–technical loss occurring in the distribution system.

The Table 5-5 below shows the system loss of the NEA over last three years.

Fiscal Year	System Loss %
#2007/2008	25.15
2006/2007	~26.5
2005/2006	~26.5

Table 5-5: System loss of the NEA over three years (2005-2008).

In the last fiscal year, the energy loss in the distribution system was 19.05%, the loss in the transmission system was 4.9% and the rest (approximately 1.2 %) came from the generation system. Since then, there has not been any major expansion in transmission or generation by the NEA. Generally, transmission loss (5%) and generation loss (1.5 %) have been constant over these years. Despite the development of the distribution network and the increase in the number of consumers, distribution loss has also been constant (19- 20%).
According to the NEA Grid Code, The Grid Owner shall ensure that the Transmission Loss does not exceed 4.5% of the Received Energy.

The NEA grid stability figures

There is no study by NEA on the measure of stability ratings. The stability of NEA is characterized by large signal stability caused by a large disturbance such as the breakdown of generators or a contingency on a heavily loaded line.

During fiscal year 2007/2008, 15 total system collapses for a total of with 317 minutes' outage occurred. Generally, it takes about half an hour to restore the system after each total system collapse. All the collapses were initiated either by a faulty line or by a generator break down. During fiscal year 2008/2009 (up to February 2009), 15 total system collapses occurred.
According to the provision stated in the Grid Code of the NEA, the System Operator ensures that the power supply voltage in the Grid during normal operating conditions should not diverge by more than **+/- 10%** of its nominal value **(230V)**.

Grid frequency
The fundamental frequency's nominal value is **50 Hz.** The System Operator ensures that the fundamental frequency in the System is maintained between 48.75 Hz and 51.25 i.e. +/- 2.5%. This is done primarily by setting the under-frequency relays at 48.75Hz. Compared to the voltage regulation, the frequency is found to be more stable in INPS.

Grid harmonics
Low level of current and voltage harmonics are desirable; higher harmonic levels increase the potential for adverse effects on connected equipment. Acceptable levels of harmonic voltage and current depend on distribution system characteristics, type of service, connected loads/apparatus, and established utility practice.
In general, the operating of the photovoltaic system should not cause excessive distortion of the utility voltage waveform or result in excessive injection of harmonic currents into the utility system.

In the INPS, no major study on the harmonics has been carried out. However, specific measurement on voltage and THD have been run between August 10th and 12th 2009 in 18 locations in Kathmandu in the framework of this project (see Table 5-6).

Mean value of THD (Total Harmonic Distortion) was **4.69, ranging from 2.6 and 6.8**.

Note: *THD is defined as:*

$$THD_v = \frac{\sqrt{\sum_{n=2}^{\infty} V_n^2}}{V_1}$$

Where:
V_1 is the rms fundamental voltage
V_n is the rms harmonic voltage of order n

S/N	Place	Measured Voltage, Volt	THD in %	Date Aug,09	Time
1	IOE/Lab/DoEE	195	6.7	10	14:00
2	IOE/DoEE/Office	216	3.9	10	14:10
3	IOE/CES	222	2.6	10	14:25
4	Lalitpur home	215	3.1	11	08:00
5	Educational Center	198	5.1	11	12:20
6	Chakupat home	211	4.2	11	12:35
7	Shop Chakupat	205	5.8	11	12:45
8	Jwagal home	212	5.2	11	13:10
9	Kupondole home	206	5.5	11	13:40
10	Shop Thapathali	212	4.9	11	13:50
11	Shop1 Anamnagar	217	3.8	11	14:30
12	Shop2 Anamnagar	205	6.7	11	14:35
13	School, Anamnagar	207	4.8	11	14:50
14	Anamnagr home	193	6.8	11	15:20
15	Radio Nepal Lab	221	3.2	11	16:25
16	Radio Nepal Studio	219	2.6	11	16:35
17	Radio Nepal control room	211	2.9	11	16:50
18	Anamnagar home	208	6.6	12	11:00
	Media	209.6	4.69		
	Dev.St.	8.40	1.47		

Table 5-6: Voltage and THD of the grid in 18 places in Kathmandu.

Mean Grid Voltage by consumer was **209.6 V, ranging from 193 V to 222 V**.

The in-situ recorded (during the measures) average voltage shows that in certain cases the network's minimal voltage can be reached.

Power Factor:
The NEAGC states that the generators shall maintain a power factor between 0.85 lagging and 0.95 leading. Similarly, distributors shall maintain power factor between 0.8 lagging and 0.95 leading, and the grid owner may disconnect the user for failing to maintain this standard.

5.2.5 Reasons for grid cuts

Grid cuts, except for the power deficit, i.e. load shedding, are mainly due to faults in the transmission lines or to the breakdown of any major generating station. Growing load demand causes congestion problems on transmission lines. Multiple interruptions and system collapses occur in the INPS due to congestion. Some of the transmission lines like the 132kV Bardhaghat-Hetauda, the 132kV Marshyangdi-Siuchatar and the 66kV Hetauda-Birgunj are experiencing severe transmission constraints.

The reasons for the total system collapses in fiscal year 2007/008 are listed in the table below:

Tripping	Frequency
Marshyangdi Power house	1
132kV Marshyangdi-Siuchatar Transmission Line	2
Kali Gandaki "A" Power house	2
132kV Bharatpur –Bardhaghat Transmission Line	2
132kV Bharatpur –Hetauda Transmission Line	4
132kV Siuchatar-Balaju Transmission Line	1
132kV Bhaktapur- Lamosangu	3

Table 5-7: Reasons of total system collapse (2007/008).

During fiscal year 2008/2009, more severe situations regarding system collapses occurred. There were 38 total system collapses, with a total duration of 1180 minutes. The average interruption time was 33 minutes, ranging from 7' to 2hr 18'. Similarly, 21 partial system collapses occurred.

38 total system collapses (1180 minutes)
Average interruption time: 33 minutes, ranging from 7' to 2hr 18'
21 partial system collapses

One of the main reason for complete system collapses between summer 2008 and summer 2009 was the tripping of 132 kV or 66kV lines, isolating some power stations. The other operating power stations were unable to compensate for the resulting deficit of several MW of power since they had little reserve margin. This kind of situation caused an "under frequency" condition in the system, resulting in complete system collapses.

5.2.6 Reactive power

The main reactive power sources are synchronous generators which are dynamic reactive sources and vary continuously according to the system demand. At substations such as Anarmani, Duhabi, Lahan, Parwanipur, Birgunj etc., static capacitors are also connected to the system. The rapidity of response of static capacitors is low, voltage support ability is poor, the reactive power generation drops with the square of the voltage, availability in the network is high and operation cost is low. Static VAr Compensators (SVC) and static compensators (STATCOM) are not yet installed in the network. Table 5-8 shows some features of the NEAs own synchronous generators, Table 5-9 gives the characteristics of the IPPs own synchronous generators and Table 5-10 depicts status of static VAr sources in the system.

S.N.	Power Plant	No. of units	Installed capacity of station(MW)	Rated MVA of one unit	p.f.	Voltage(kV)	Rated MVAr of one unit	Rated MVAr of station
1	KG-A	3	144	56.5	0.85	13.8	29.76	89.29
2	MRS	3	69	30	0.85	11	15.80	47.41
3	KL-I	2	60	35.3	0.85	11	18.60	37.19
4	KL-II	2	32	18.8	0.85	6.6	9.90	19.81
5	Trishuli	7	24	3.889	0.9	6.6	1.70	11.87
6	Devighat	3	14.1	5.875	0.8	6.6	3.53	10.58
7	Gandak	3	15	5.9	0.85	6.6	3.11	9.32
8	Modi	2	14.8	7.8	0.9	6.6	3.40	6.80
9	Sunkoshi	3	10.05	3.941	0.85	6.3	2.08	6.23
10	Puwakhola	2	6.2	3.7	0.85	6.6	1.95	3.90
11	Multifuel	6	39	8.144	0.85	11	4.29	25.74

* Data source: Generation Report, 5th issue, Bhadra, 2064, Nepal Electricity Authority.

Table 5-8: Some features of NEA own synchronous generators.

S.N.	Power Plant	No. of units	Installed capacity of station(MW)	Rated MVA of one unit	p.f.	Rated Voltage (kV)
1	Khimti	5	60	14.2	0.86	10.5
2	Bhotekoshi	2	36	25	0.9	11
3	Chilime	2	22.1	13	0.85	11
4	Jhimruk	3	12	5	0.8	6.6
5	Indrawati	3	7.5	3.125	0.8	6.6

*Data source: Generation Report, 5th issue, Bhadra, 2064, Nepal Electricity Authority.

Table 5-9: Some features of IPP own synchronous generators.

S.N.	Station name	Reactive power source/sink	Rated MVAr	Rated voltage (kV)
1	Anarmani	Shunt capacitor	15	33
2	Duhabi	Shunt capacitor	42	33
3	Lahan	Shunt capacitor	20	132
4	Parwanipur	Shunt capacitor	10	11
5	Birjung	Shunt capacitor	10	11,33
6	Lamahi	Shunt inductor	10	132
7	Attaria	Shunt inductor	10	132

*Data source: Grid Operation Department, 2007, Nepal Electricity Authority.

Table 5-10: Static reactive sources in the INPS.

Provision on the NEA Grid Code concerning Reactive Power

The NEA Grid Code (NEAGC) specifies two parameters for power quality: voltage and frequency variations. Concerning voltage variations, the system operators shall ensure that the power supply voltage in the grid at major connection point during normal operating condition shall not deviate by more than +/- 10 percent of its nominal value. The NEAGC states that the generators shall maintain a power factor between 0.85 lagging and 0.95 leading. Similarly, distributors shall maintain power factor between 0.8 lagging and 0.95 leading, and the grid owner may disconnect the user for failing to maintain this standard. Under the grid management procedure, the NEAGC specifies some procedures for voltage management. According to these procedures, the system operator shall conduct load flow studies of the system for different conditions and determine the optimum generation that would also provide acceptable voltage profile at each connection point. Generating units shall be equipped with automatic voltage controllers (AVR). Power system stabilizers, if provided, shall be tuned properly in consultation with the system operator. The NEAGC further states: if an acceptable voltage level cannot be achieved through optimum generation, the control of the voltage shall be achieved by managing the reactive power supply in the gird. These include the operation of the following equipment:

- Synchronous condensers
- Static condensers
- Static VAR compensators
- Shunt reactors and capacitors
- On-load tap changing transformers

From these statements, we can conclude that the grid code simply specifies the range of operating power factor, voltage deviation and operational sequence for voltage management. There is however no financial compensation or penalties for respecting or violating the standards. There is no form of encouragement for the installation of reactive power sources in the system, since there is no discrimination on the contribution of reactive power source in the network. The NEAGC does not evaluate the contribution of reactive source even though they are operating in the specified operational band.

5.3 Economy of the electricity sector in Nepal

5.3.1 Generation costs

The NEA follows a minimal cost generation expansion plan in order to choose economic projects. A WASP programme is run with the capacity and energy of all proposed plants, their cost, the forecasted demand and energy as input. Transmission planning is mainly performed for power evacuation of new plants and for the reinforcement of the existing transmission lines, so as to improve the power transfer capability and reduce loss. The transmission route, conductor, voltage level, and the number of circuits are determined as per the requirement of power transfer and loss reduction.

The average generation cost of generation system owned by the NEA is 2.76 [NPR/kWh] (ca. 0.039 [CHF/kWh]). The generation cost of some generation plants are mentioned below. The cost includes operation, maintenance and capital investment (i.e. the depreciation) (NEA, 2008). Note that 2.76 [NPR/kWh] is the average cost for the NEA for energy it generates itself 4.08 [NPR/kWh] is the average cost for the NEA for energy generated by itself as well as by IPPs and 5.08 [NPR/kWh] is the average cost for the NEA for the energy produced by IPPs only.

Plant	Gen. Cost [NPR/kWh]	Gen. Cost [CHF/kWh]
Kulekhani I (Storage Hydro)	1.90	0.027
Devighat (Hydro)	1.47	0.021
Hetauda Diesel (Diesel Thermal)	31.50	0.450
Duhabi Multifuel (Furnace oil based thermal)	29.40	0.420

The composition of cost for the fiscal year 2005-2006 is detailed in the figure below.

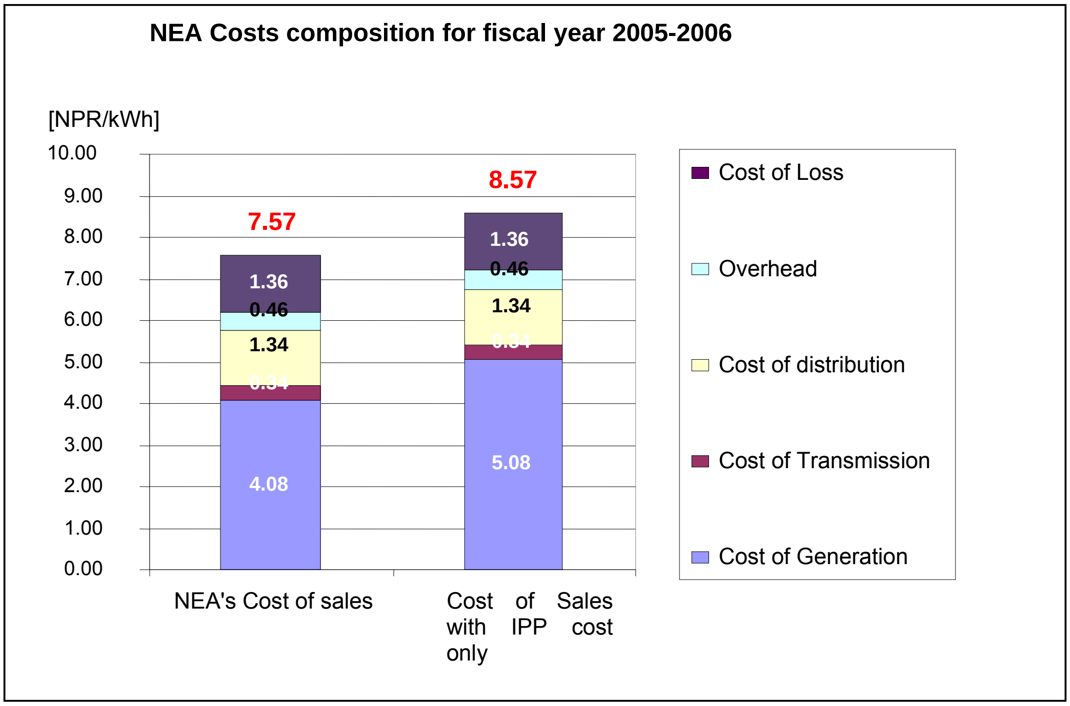
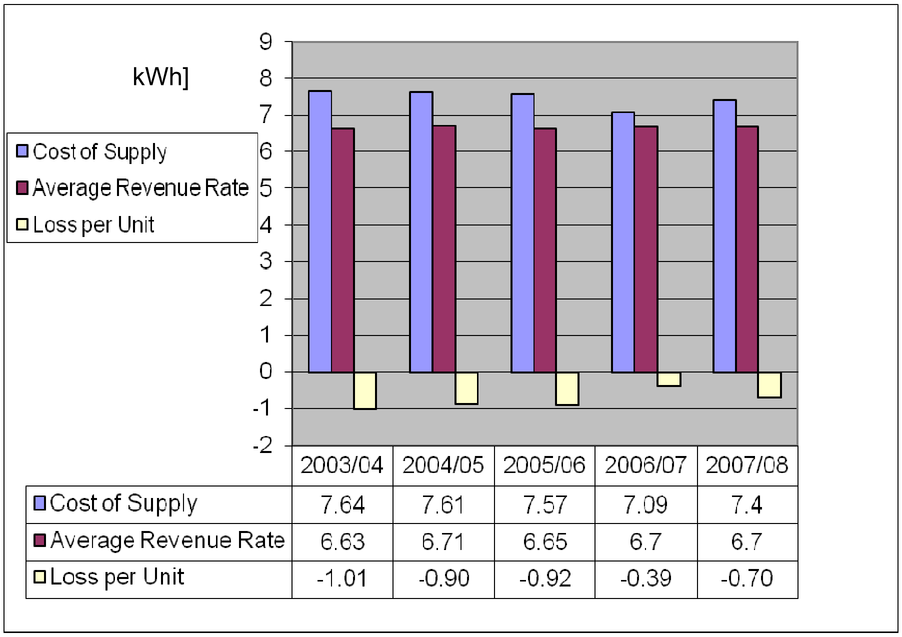


Figure 5-6: Composition of NEA costs for the fiscal year 2005-2006.

5.3.2 Selling costs

Despite the general price increase for most goods, the NEA has not yet been allowed to adjust the selling price of electricity and had, for the fiscal year 2007-2008, to bear a loss of approx. 0.42 [NPR/kWh] (ca. 0.006 [CHF/kWh]) corresponding to the difference of supply cost and revenue as detailed in the table below (0.70-0.28 [NPR/kWh] coming from miscellaneous incomes) (NEA, 2008).
The cost of electricity for the consumers has to be put into relation with the average level of earnings of the population, which is estimated here (for Kathmandu, April 2009).

- Lower middle class salary level: ca. 8’000 - 10’000 [NPR/month]
- Middle class: 15’000 – 20’000 [NPR/month]
- Upper Middle class: 21’000 - 50’000 [NPR/month]
- Upper class: above 50’000 [NPR/month]



	2003/04	2004/05	2005/06	2006/07	2007/08
Cost of Supply	7.64	7.61	7.57	7.09	7.4
Average Revenue Rate	6.63	6.71	6.65	6.7	6.7
Loss per Unit	-1.01	-0.90	-0.92	-0.39	-0.70

Figure 5-7: Evolution of supply and revenue cost from 2003 to 2007.

The detailed tariff structure is presented in the table below.

1:	DOMESTIC CONSUMERS			
	A	Minimum Monthly Charge : METER CAPACITY	Minimum Charge (NRs.)	Exempt (kWh)
		Up to 5 Ampere	80.00	20
		15 Ampere	299.00	50
		30 Ampere	664.00	100
		60 Ampere	1394.00	200
		Three phase supply	3244.00	400
	B	Energy Charge:		
		Up to 20 units	Rs. 4.00 per unit	
		21 - 250 units	Rs. 7.30 per unit	
		Over 250 units	Rs. 9.90 per unit	
2:	TEMPLES			
	Energy Charge		Rs. 5.10 per unit	
3:	STREET LIGHTS			
	A	With Energy Meter	Rs. 5.10 per unit	
	B	Without Energy Meter	Rs. 1860.00 per kVA	
4:	TEMPORARY SUPPLY			
	Energy Charge		Rs. 13.50 per unit	
5:	COMMUNITY WHOLESALE CONSUMER			
	Energy Charge		Rs. 3.50 per unit	
6:	INDUSTRIAL		Monthly Demand Charge (Rs./kVA)	Energy Charge (Rs./unit)
	A	Low Voltage (400/230 Volt)		
		(a) Rural and Cottage	45.00	5.45
		(b) Small Industry	90.00	6.60
	B	Medium Voltage (11 kV)	190.00	5.90
	C	Medium Voltage (33 kV)	190.00	5.80
	D	High Voltage (66 kV and above)	175.00	4.60
7:	COMMERCIAL			
	A	Low Voltage (400/230 Volt)	225.00	7.70
	B	Medium Voltage (11 kV)	216.00	7.60
	C	Medium Voltage (33 kV)	216.00	7.40
8:	NON-COMMERCIAL			
	A	Low Voltage (400/230 Volt)	160.00	8.25
	B	Medium Voltage (11 kV)	180.00	7.90
	C	Medium Voltage (33 kV)	180.00	7.80
9:	IRRIGATION			
	A	Low Voltage (400/230 Volt)	-	3.60
	B	Medium Voltage (11 kV)	47.00	3.50
	C	Medium Voltage (33 kV)	47.00	3.45
10:	WATER SUPPLY			
	A	Low Voltage (400/230 Volt)	140.00	4.30
	B	Medium Voltage (11 kV)	150.00	4.15
	C	Medium Voltage (33 kV)	150.00	4.00
11:	TRANSPORTATION			
	A	Medium Voltage (11 kV)	180.00	4.30
	B	Medium Voltage (33 kV)	180.00	4.25

Table 5-11: Electricity tariff structure. Unit = [kWh] (NEA, 2009)

Medium and high voltage tariffs are subject to “Time of the Day” variations, as per the following table:

		Consumer Category & Supply Level	Monthly Demand Charge (Rs./kVA)	Energy Charge (Rs./unit)		
				Peak Time	Off-Peak	Normal
				18:00-23:00	23:00-6:00	6:00 - 18:00
A:	**High Voltage (66 kV and Above)**					
	1	Industrial	175.00	5.20	3.15	4.55
B:	**Medium Voltage (33 kV)**					
	1	Industiral	190.00	6.55	4.00	5.75
	2	Commecial	216.00	8.50	5.15	7.35
	3	Non-Commercial	180.00	8.85	5.35	7.70
	4	Irrigation	47.00	3.85	2.35	3.40
	5	Water Supply	150.00	4.55	2.75	3.95
	6	Transportation	180.00	4.70	2.95	4.15
	7	Street Light	52.00	5.70	1.90	2.85
C:	**Medium Voltage (11 kV)**					
	1	Industiral	190.00	6.70	4.10	5.85
	2	Commecial	216.00	8.65	5.25	7.55
	3	Non-Commercial	180.00	9.00	5.45	7.85
	4	Irrigation	47.00	3.95	2.40	3.45
	5	Water Supply	150.00	4.60	2.80	4.10
	6	Transportation	180.00	4.80	3.00	4.25
	7	Street Light	52.00	6.00	2.00	3.00

Table 5-12: Time of the day tariff rates. Unit = [kWh] (NEA, 2009).

Remarks:

a) If demand meter reads kilowatts [kW], then kVA = kW/0.8
b) 10 % discount in the total bill amount will be given to the GON approved Industrial Districts
c) 25% discount in the total bill amount will be given to the GON Hospitals and Health Centres (except residential complexes)

5.3.3 Electricity market and consumers profiles

The main market for the electricity generated in Nepal is internal sale, while a small portion (less than 10%) is exported to India. The main electricity consumers are households and industries, accounting for respectively 42% and 40% of total power used in F.Y 2007/08. Although the growth rate in the demand for power in industries has exceeded that of households over the past decade, these two sectors account for roughly 82% of the total electricity demand. Commercial (7%), non-commercial (6%), water supply and irrigation (2%) and street lighting (3%) account for the remaining 18%.
Electricity use is characterized by a load profile dominated by a large number of household connections and relatively few industry consumers. In 2008, the domestic sector accounted for 95% of customers while the industrial sector accounted for less than 2%, and the combined commercial and non-commercial consumers for 2%.
The table below shows the evolution of the electricity consumption by user categories from 1999 to 2008.

The main consumers of electricity are households (42%) and industries (40%)

									in [GWh]
Category	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008***
Domestic	410.57	467.05	518.36	557.94	617.11	676.37	758.19	805.72	893.27	951.84
Non-commercial	62.93	63.59	73.16	78.22	80.74	83.01	100.54	95.29	100.52	108.9
Commercial	77.34	81.82	94.17	90.43	92.74	108.12	109.31	120.3	141.69	159.37
Industrial	441	508.36	520.63	596.68	629.51	689.8	764	785.55	849.13	911.67

Water Supply & irrigation	22.83	15.74	25.6	29.28	29.98	31.67	49.98	45.5	47.96	47.5
Street Light	29.41	31.74	36.98	39.52	45.8	55.2	54.86	63.24	66.9	72.58
Temporary Supply	0.77	0.93	0.83	0.28	0.35	0.25	0.39	0.87	1.26	0.7
Transport	2.6	2.68	5.89	5.64	5.53	5.47	5.8	5.65	6.31	6.03
Temple	1.98	2.37	2.51	2.48	2.81	4.11	4.58	4.77	4.78	5.37
Community Sales	-	-	-	5.72	4.74	5.58	6.03	9.18	15.51	23.45
Total (internal Sales)	1049.43	1174.3	1278.1	1406.2	1509.3	1659.6	1853.7	1936.1	2127.3	2287.4
Bulk supply (India)	64.16	95	126	133.86	192.25	141.23	110.7	96.55	76.87	61.5
Grand Total	1113.59	1269.3	1404.1	1540.1	1701.6	1800.8	1964.4	2032.6	2204.2	2348.9
* Provisional figures; subject to final audit										

Table 5-13: Electricity consumed by consumer category in Gigawatt hour (1999-2008). (NEA, 2008).

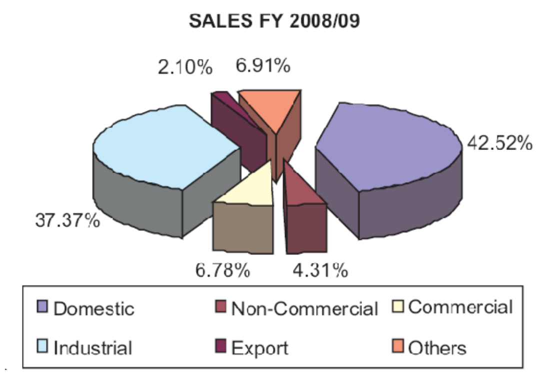


Figure 5-8: Repartition of electricity sales according to users categories. (NEA, 2009)

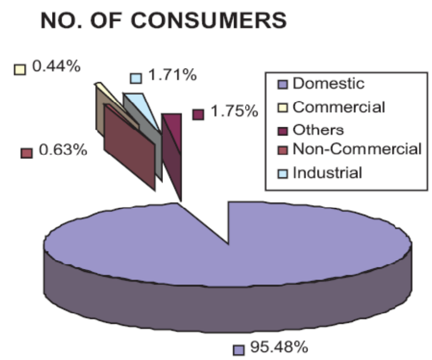
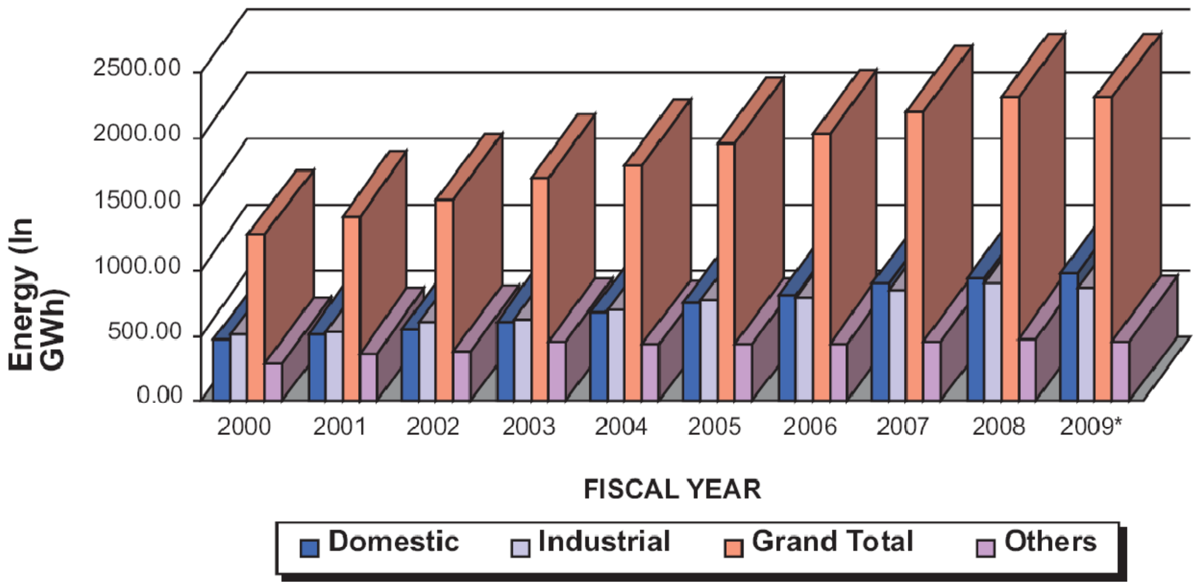


Figure 5-9: Number of electricity consumers according to users categories. (NEA, 2009)

The consumption is broadly categorized as domestic, industrial and others. Total domestic consumption was 410 GWh in 1999 which increased over the years to reach 950 GWh in 2008. The annual electricity consumption growth fluctuated between 6% (2006 and 2008) and 13% (2000), with an average at 10%. Similarly, the industrial consumption was of 440 GWh in 1999, and grew over the years to reach 910 GWh in 2008. Growth varied between 15% (2000) and 5%. Energy consumed by other categories was approx. 200 GWh in 1999, and it increased to nearly 400GWh in 2008.

Total consumption was approx. 1100 GWh in 1999, it increased over the years to reach nearly 2300 GWh in 2008. The average growth rate was 8%. The annual growth rate fluctuated between 7% and 11. During the same period, the yearly population growth averaged at 2% only. Despite the drastic increase in electricity consumption during the last decades, the average yearly consumption per capita remain extremely low in Nepal, with a value of only 80 [kWh/per year]. This is partly due to the fact that so far only a limited part of the population has access to electricity (ca. 1.5 million domestic user connections in 2008 for a total population of 28.5 million). (NEA, 2008) and (CIA).

The graph below shows the evolution of the electricity consumption between 2000 and 2009 for the three main categories of users: domestic, industrial and others.



*Provisional figure subject to final audit

Figure 5-10: Evolution of electricity consumption by users categories from 2000 to 2009. (NEA, 2009).

5.3.4 Load shedding history and perspectives

People of Nepal have been facing load shedding continuously since the 2005-2006 fiscal year. The duration of the load shedding rose to a maximum of 16 hours per day during spring 2009. With an average growth rate of 10%, the total growth in demand during the last three years was 205 MW. However, the total added capacity in the last three years was only 5.85 MW. The unmet additional demand of approximately 200 MW is the main reason explaining the load shedding situation.

The actual "hydro reservoir capacity" is rather limited (about 4 hours, up to 20 hours for some reservoirs), which makes the storage of hydro power and time scaling of distribution difficult. Even during the rainy season, load shedding cannot always be avoided because of this as well as because of the high water speed that creates regular damage which needs to be repaired. A large amount of hydro power potential is consequently left unused. Besides, about two thirds of urban householders have installed batteries with inverters as a small backup system during load shedding periods. These are aggravating the issue, like demonstrated in the simulations realized in chapter 6.2. The table below gives the comparative picture of energy demand and installed capacity.

Fiscal Year	Peak Power Demand [MW]	Growth Rate [%]	Energy annual demand [GWh]	Installed Capacity [MW]
2005/006	603.28	8.20	2842.7	611.53
2006/007	648.39	7.50	3151	
2007/008	721.73	11.30	3512.8	
2008/009	808.00	12.00	Contd..	617.38*

* Middle Marshyangdi considered in trail operative stage.

Table 5-14: Evolution of energy demand and installed capacity since 2005.

The maximal daily load shedding duration and the amount of energy and demand shed are listed in the table below. The maximum load shedding in 2009 was expected to be 9 hours per day. However, due to contingencies such as the destruction of the Kataiya – Duhabi 132 kV transmission link by the Koshi flood, the load shedding peaked to 16 hours per day. This is the maximum duration in the history of load shedding in the country.

Load Shedding

Fiscal year	Max hrs/ day	MW	MWh
2005-2006	2	110	71'050
2006-2007	3	120	105'139
2007-2008	6	265	309'460
2008-2009	16*	450	NA

*Expected load shedding was 9 hours per day

Table 5-55: Duration and Capacity of Load Shedding.

A high level committee was formed by the Ministry of Water Resources in 2008 for advising the government in solving load shedding problems. The committee was coordinated by the General Manager, the NEA with members from the FNCCI, the NCC, the HAN and the MoE. The committee's report mentioned a long term load shedding plan as per the following table.

Fiscal year	Max hours per day	Months of max load shedding
2007-2008	8	Jan.-Feb.
2008-2009	9	Feb.-March
2009-2010	10	April
2010-2011	13	Feb.-March-Apr.
2011-2012	15	Feb.-March-Apr.
2012-2013	7	Feb.-March-Apr.

Table 5-66: Load shedding perspective plan of the NEA.

The expected load shedding scenario with additional power import through the cross border link is presented in the table below.

Fiscal year	**Dec**	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**[MWh]**
2007-2008 Load Shedding hours	2	6	8	5	5	3		
2008-2009 Load Shedding hours	2	4	5	6	6	4		
2009-2010 Load Shedding hours	2	5	7	9	10	7	2	
Import through cross border link [MW]		110	110	110	110	110		396'000
2010-2011 Load Shedding hours	4	9	13	13	13	10	6	
Import through cross border link [MW]	140	140	140	140	140	140	140	705'600
2011-2012 Load Shedding hours	8	13	15	15	15	14	9	
Import through cross border link [MW]	170	170	170	170	170	170	170	856'800
2012-2013 Load Shedding hours	1	4	5	7	7	7		
Import through cross border link [MW]	140	140	140	140	140	140		604'800

Table 5-77: Load shedding Plan of the NEA with additional power imports from India.

5.3.5 Power Import/Export

Nepal imports and exports power from and to India. In 2007, the net energy received from India was 328.83 GWh, a figure that increased to 412.41 GWh in 2008. Power exchange between Nepal and India occurs at different voltage levels. As per the provision of Mahakali treaty, Nepal receives 70 millions of kWh of annual energy (20 MW) from Tanakpur at 132kV. In addition to the “free” energy, Nepal has recently imported 20 MW of supply from Tanakpur at commercial rates. Similarly, as provisioned in the Koshi treaty, Nepal receives approximately 10 MW of power from the Koshi Project, supplied through three 33 kV circuits to Rajbiraj, Duhabi and Inaruwa.
According to the power exchange agreement between India and Nepal, approximately 40 MW of power is being imported from Kataiya through the 132 kV Kataiya-Duhabi link, and it has been agreed by both nations to increase it to 60 MW to help to solve the prevailing power crisis in Nepal. Altogether, it has been agreed to increase the total power exchange level from 50 MW to 150 MW. The NEA is studying new power import possibilities through other 33kV links between Nepal and India on the basis of the "National Electricity Crises Management Action Plan 2008-2009", approved by the Cabinet of Ministers on December 24th, 2008. There are several transmission bottlenecks that hinder increasing the scale of power exchange with India. Hence, additional high voltage, cross-border links between India and Nepal are necessary. After the construction of the cross-border links, which is expected to be completed by the end of 2009/2010, it will be possible to import power at low tariffs under a long term power purchase agreement.
The 8th meeting of the Indo-Nepal Power Exchange Committee, held in Kathmandu in June 2007, revised the annual escalation rate of power exchange to 5.5%. Accordingly, the tariff statement for power exchange between Nepal and India is listed below:

Year	**Tariff for System Voltage [NPR/kWh]**			
	11kV	**33kV**	**132kV**	**Koshi Supply**
2008 Jan.–June	4.05	3.77	3.49	2.70
2008 July– Dec.	4.15	3.86	3.57	2.75
2009 Jan.- June	4.26	3.96	3.66	2.83

Table 5-88: Tariffs of India-Nepal Power Exchange.

5.3.6 Electricity market development perspectives

The electricity sector of Nepal has two market perspectives:

- Internal
- External, i.e. export to India

Rural electrification and industrialization are the main electricity markets in Nepal. The internal electricity demand is growing at an average rate of 8%. According to this growth rate, the demand will reach 1’804 MW in 2020 (it might become much higher if economic growth increases in these years). Nepal has abundant lime stone belts, and cement factories are among the largest industrial electricity consumers. If electricity and distribution networks were available, many cement factories could be established. Fertilizer manufacturing industries also require a large amount of electricity, such industries could be established when power is available, producing both for internal consumption and export.
Nepal has abundant opportunities for future power trade with India. Northern regions of India (Uttar Pradesh and Delhi) have power shortages that will probably continue in future. Load characteristics are such that the demand is high during summer, when the efficiency of thermal steam turbines goes down. Nepal has abundant potential hydro energy which could offer seasonal power. Additional available seasonal hydro energy can facilitate maintenance of steam turbines; in winter, hydro generation lowers, making it the ideal time for maintenance. Nepal’s forecasted peak demand for 2020 is 1’804 MW, which compares to an economically feasible potential of 42’000 MW. Initial studies have been completed to develop 22’458 MW. Hence, there is significant scope for export without compromising domestic requirement. However, the achievement of large hydro power plants able to produce such quantities of energy will take many years (about ten years in a stable political-economic context). NEA will have to find important funds and face sensitive social and environmental issues. The solutions for resolving the current electricity crisis at relatively brief term are thus probably to be found in the diversification and decentralization of power production sources.

5.3.7 Incentives for Renewable Energies

Different fuels and energy sources have different values in terms of efficiency and convenience. They generate different kinds and amounts of pollution. Their relative prices need to be set in a way that the resulting choices are socially, economically and environmentally acceptable. Pricing of one form of energy should not be set independently from the other. Integrated policy requires a consistent tax structure, a uniform treatment of externalities, and consistent regulation. An integrated energy policy needs to clearly recognize the trade-offs in energy choices in an economy, and optimize these choices in such a way that the end uses for which energy is demanded are met in the most efficient way and at better cost. Incentives schemes are means that can serve to encourage the use of renewable energy sources, even when their costs are not yet competitive in comparison to those of non-renewable energy sources.

In Nepal, the Alternative Energy Promotion Centre is responsible for the development and promotion of renewable and alternative energy technologies. So far, AEPC is providing incentives to the following technologies:

1. Biogas
2. Micro-Hydro Power (MHP)
3. Improved Cooking Stove
4. Solar Energy System
5. Wind Energy

The table below is a synthesis of the incentive scheme proposed by AEPC. All necessary details are presented in the subsidy (AEPC, 2006a) and (AEPC, 2006b), available at: http://aepc.gov.np

Technology	Description	Incentive [NRP]
Biogas plants, GGC 2047 Model of capacity 4-10 m^3	For 20 districts of Terai	6’000.- per plant
	For 40 hilly districts with road access	9’000.- per plant
	For 15 remote districts without road access	12’000.- per plant
	Specified low penetrated districts will be provided with additional subsidy of	500.- per plant
	4-6 m^3 capacity plants will be provided with additional of	500.- per plant
Micro-Hydro Power MHP	new MHP project ≤ 5 kW	8’000.- per HH, max. 65’000.-
	New MHP project > 5 kW and ≤ 500kW	10’000.- per HH, max. 85’000.-
	Addition on MHP project for Improved Water Mill (if it is for electrifying villages)	4’000.- per HH, max. 40’000.-
	Rehabilitation of MHP project > 5 kW	10’000.- per additional HH, max. 85’000.-
	Transportation of equipment and materials	0.- to 3’000.- per HH, according to regions
Improved Cooking Stove	Solar Cooker	50% of cost, maximum 4’000.-
	Improved cook stoves in High Mountains	50% of cost, maximum 4’000.-
Solar Energy System (PV)	SHS ≥ 10 and ≤ 18 Wp	5’000.- per HH for accessible VDCs 6’000.- per HH for remote VDCs 7’000.- per HH for very remote VDCs
	SHS > 18 Wp	6’000.- per HH for accessible VDCs 8’000.- per HH for remote VDCs 10’000.- per HH for very remote VDCs
	Solar pumps (PV) ≤ 1 kWp, in the areas where rural electrification has not been done	75 % of cost

	SHS used by public institutions such as the VDC buildings, School, Club, Health post/ Centre etc.	75 % of cost
	*Solar tuki, s*mall SHS based on White LED consisting of 2-5 Wp solar panel along with two sets of solar lamp	50% of cost, maximum 1'250.-
	In Project since 2009: SHS in areas with access to grid, up to 100'000 SHS	Tax free on modules supply 50% of cost, maximum 10'000.-
Wind Energy	Feasible wind electrification projects based on wind chargers to provide lights in village will be provided subsidy at a rate similar to solar home system based on the number of households served by each installation. The financial and technical support will be provided for pilot wind projects if the electricity generated from it is used for provision in the remote areas where there is no access to the national grid, MHP.	
Various equipments	Solar Dryer	50% of cost for family use, max. 10'000.- 70% of cost for comm. use, max. 14'000.-
	Improved water mill for Grinding	9'000.-
	Improved water mill for Hulling and Grinding	18'000.-
	Add. subs. for remote districts for Grinding	1'500.-
	Add. subs. for remote districts for Hulling and Grinding	3'000.-

Table 5-99: Synthesis of AEPC incentives scheme for renewable energies, source: (AEPC, 2006b), (Shrestha, personal communication, 2009).

5.4 Main stakeholders point of view

Semi-structured interviews with representative stakeholders of the electricity sector in Nepal were conducted in order to provide an overview of the various points of view concerning the specific issue of grid-connected PV technology in the country. Senior representatives of the following public and private institutions and companies were interviewed: MoWR (now MoE), AEPC, DOED, NEA, DANIDA, SEMAN, CEDB. Also, PV material and systems suppliers as well as real estate developers were interviewed. Their perception on the issue is synthesised below.

On the overall feasibility of PV grid connection in Nepal

Most of the representatives basically agree on the fact that grid-connected PV technology is appropriate in the Nepalese context, that it has good chances of becoming a reality in the coming years, and that they would support its implementation if the framework conditions are favourable. Among the institutions in charge of regulation and implementation of electricity generation and distribution, there is also a general consensus in favour of grid-connected PV technology as part of the country's generation package. Nonetheless, it is also recognized that this technology is not a unique solution that will resolve the issue of the power generation gap and current energy crisis alone, but rather, that it should be considered in conjunction with other complementary technologies. Various institutions state that the GoN would facilitate the introduction of new power generation capacities that can be implemented in the short term, in order to somewhat compensate the gap in generation capacity until new hydro power plants can be made operative (by ca. 2012-2019). It is estimated that, in the present situation, 50 to 60 MW of produced capacity by grid-connected PV systems could be absorbed without problems by the grid system. However, some of the stakeholders have expressed reluctance (particularly some PV material distributors), and pointed out various obstacles and difficulties in relation to grid-connection PV applications, as summarized in the following sections.

On the hindrances of grid-connected PV development in Nepal

- *Cost is still too high;*
- *Grid stability and reliability are not sufficient (voltage and frequency variations, power interruptions);*
- *A 33 kV station (that is not subject to load shedding) must be available nearby in order to make grid connection possible;*
- *Difficulties in absorbing peak power of PV plants during the lowest needs period (from 11am to 3pm);*
- *PV power production will not be sufficient to fill the gap anyway;*
- *Knowhow and appropriate professional skills are seriously missing among PV market actors in Nepal, the need of well trained and educated professionals is high, especially among dealers;*
- *Social acceptance of the technology might be problematical;*
- *It takes a lot of space to install PV modules, the land around KTM Valley is fully occupied for farming purposes, there is no space for PV plants. Urban flat roofs could be utilized for installing PV modules but it is important to consider that those have an important meaning for the users (are used for cloth washing, as an outdoor space and for social gatherings);*
- *New Power Purchase Agreements need to be defined.*

On the issues related to electricity and PV market in Nepal

- *Public and users pressure the NEA and its staff with regards to the energy crisis and load shedding issue;*
- *Price of electricity should be increased by 20% to be viable for the NEA but this is currently politically not acceptable (NEA has already tried to accomplish this in the past, but did not obtain political acceptance);*
- *NIPQUA standards are good, but there isn't sufficient control of their observance and respect;*
- *IEC standards are theoretically necessary for distribution in Nepal, but the controls are not possible so far;*
- *PV market is developing fast (mainly because of the energy crisis) but only for standalone systems;*
- *IT industries would be ready to acquire electricity at the rate of 45 [NPR/kWh] if they had the guarantee of 100% (24 hours, 7 days/week, 365 days/year) safe supply;*
- *Rich people are willing to pay about 30-40 [NPR/kWh] for electricity;*
- *SEMAN fixes the price levels for the importation of goods (PV modules) and is in charge of giving the approval for "tax reduction importation" (2.5% of import tax instead of 34%). The approval is also subject to the RETS certification (NIPQA standard to be respected);*
- *Prices of PV modules, when compared to India and China, are more or less the same. For Nepal, they follow the following structure: ca. 4 [USD/Wp] (at factory) + 16% for transportation + 30% as*

company margin (same as in India). The final cost in rural areas is about 10 [USD/Wp], including 2-3 dealers in between (April 2009);

- *Concerning imports from India and China: 2 module qualities and 2 module prices are available: 1) "A" quality corresponding to real IEC standard modules and 2) "B" quality corresponding to "fake" IEC standard modules. Since no proper control on IEC standards are possible, it seems that most of the modules imported in Nepal are of "B" quality but at the cost of "A" quality.*

  Note of the authors: it seems that dealers take advantage of this system. Without a possibility for real quality controls, they manage to sell "B" quality at the price of "A" quality. However, PV grid connection would make this much more difficult because the modules productivity would then be measurable. This might be a reason why some PV module distributors are reluctant towards grid-connected PV.

On the solutions for resolving the current energy crisis

- *Within 5 years, new hydro power plants should be ready to produce sufficient energy (700 MW by 2014 according to NEA 2007-2008 annual report);*
- *There is no ready alternative for covering the gap in power supply for the next 10 years (necessary time to develop further hydro), the only solution is to import energy from India, but the capacity of existing transport lines (100MW) is not sufficient (450 MW would be necessary);*
- *The import of 200-250 MW from India would be a minimum base to avoid current load shedding (but the transmission line capacity is not sufficient and various entry lines should be used);*
- *Facilitating the construction of new hydro power plants in the short term (through emission of licenses). Several licenses have been issued for ca. 7'000 MW (run-of-the-river-ROR) projects, but those are blocked partly because of the political instability. Some might be launched soon.*
- *The reservoir capacity of current hydropower production systems is insufficient. Some studies on new reservoirs are ongoing.*
- *Diesel run plant generators to cover the peak demand until sufficient hydro production capacity is installed;*
- *Increasing the cost of energy, but this is politically not feasible;*
- *At medium term (3-5 years), build 6-7 new hydro plants (1 > 450 MW)*

Ideas and suggestions to facilitate the development of PV grid connection in Nepal

- *Grid-connected PV technology needs to be developed in close conjunction with hydro production schemes and characteristics;*
- *In Nepal, grid-connected PV projects would be more appropriate if realized in a centralized way rather than at the household scale;*
- *If the introduction of new technologies (such as grid-connected PV) is driven by the public (households), then it will have more chances to succeed and there will be no reason for the institutions not to accept it. Building people's awareness of the advantages of such technology is necessary;*
- *The technology has to be commercially viable otherwise it will never be really adopted. "Normal" and acceptable payback time should be around 5 years (but in energy crisis times it could be 10 years);*
- *In order to be able to invest, the private sector needs to find appropriate conditions in terms of technical, fiscal and legal conditions. They should be in place to make PV grid connection attractive for investments from the private sector;*
- *Free market conditions for the import of PV material would be necessary in order to increase the competition and lessen the costs;*
- *Central Bank (Finance Ministry): could determine advantageous interest rates (6-7%) for PV plants. This would make it affordable for the upper-middle class;*
- *CEDB would be ready to provide advantageous financing conditions for grid-connected PV technology (ca. 9% interest rate instead of 11%);*
- *There is a need to convince decision makers on the advantages and solutions provided by grid-connected PV technology;*
- *Government subsidies schemes are needed;*
- *In Calcutta, it is compulsory in the building code that new housing settlements must have SHS for lighting. This could be reproduced in urban Nepal;*
- *Architects should promote the use of PV grid-connected solutions in their projects;*
- *Possible pilot plant locations in urban and semi-urban areas and within the "non load shedding" areas: hospitals, ministries, industries, mini-grid, retrofitting of existing NEA PV plants that aren't in function anymore, cluster of houses with possibly mini-grid.*

5.5 Domestic users' point of view

A survey with a selected group of potential domestic users was carried out. In order to focus the assessment on a category of people that present preliminary conditions to be possible future users of PV grid-connected technology, middle-upper class families within the Kathmandu agglomeration (including Lalitpur) were interviewed. Three hundred and nineteen (319) households provided valid feedbacks to the structured interview (see annex 2, questionnaire to domestic/private sector potential users).

Question 1: *How do you manage power supply during load shedding periods?*
More than half (54.5%) of the owners use "Inverter-Battery Systems", a solution which consists in charging batteries from the grid when it is in function. Due to the drastic increase of load shedding periods, this system has become very popular in Kathmandu because it is relatively affordable (for this category of the society), easy to install and to run. However, considering the losses of such systems, its use at a large scale contributes to further worsen the problem of load shedding. About one third (30.1%) of the households just deal with the inconvenience, without using any specific alternative source of electricity. This high figure demonstrates the serious lack of appropriate alternative. About ten percent (9.7%) make use of solar PV-battery systems, this is relatively high considering the investment cost for the system and the fact that this solution is not yet supported by incentives in urban areas (such incentives are planned but not implemented yet, see chapter 5.3.7). However, a high number of the latter only opt for a small size system, used mainly for emergency lighting purpose. Six percent (6%) did not provide an answer. About four percent (4.1%) use diesel generators, which appears to be a small number. This is probably due to the chronic diesel supply crisis. Very few petrol and LPG generators are used because they cost more to run compared to diesel plants.
Diesel gensets are mainly considered for small industries, services and tourism. For individual households, petrol gensets or inverters are used more often.

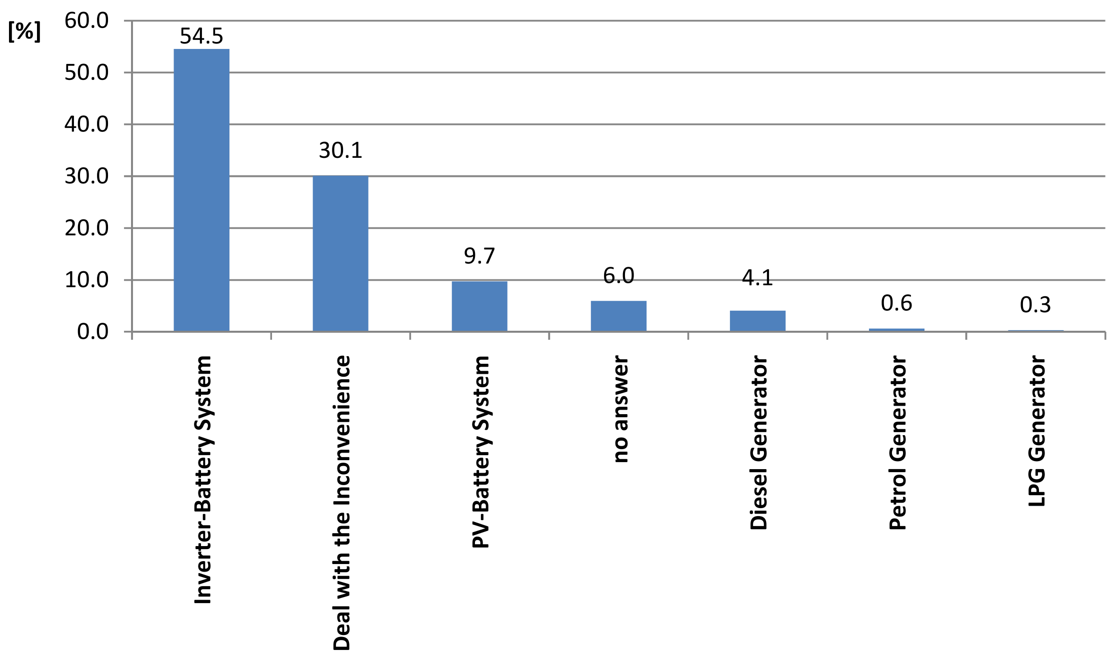


Figure 5-11: Management of power supply during load shedding periods by domestic users.

Question 2: *How much are you ready to pay for a reliable power supply 24 hours / 7 days? Knowing that:*

- *The actual cost of your electricity is 7,30 [NPR/KWh]*
- *Your average monthly consumption is about 300 [KWh], costing about 2'200 [NPR/month]*
- *The cost of electricity for a home system with a generator is*
  - *Diesel generator: about 50 [NPR/KWh] size (domestic)*
  - *Petrol generator: about 60 [NPR/KWh] size (domestic)*
  - *LPG generator: about 60 [NPR/KWh] size (domestic)*

About three quarters (74%) of the owners would agree to pay 10 [NPR/kWh] for such a service, which represents a cost increase of 37% compared to the current average electricity unit cost. One fifth (20.1%)

can afford to pay 20 [NPR/kWh] (increased cost of 174%), about three percent would even pay 30 [NPR/kWh] (increased cost of 310%), and very few would be ready to pay up to 50 [NPR/kWh].

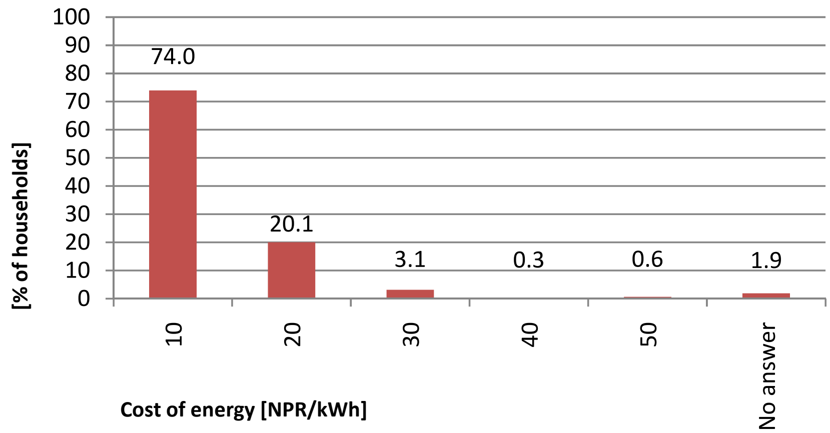


Figure 5-12: Willingness to pay for a reliable power supply (Domestic users).

<u>Question 3</u> relates to the type of electric appliances that people use at home and is summarized in the figure below.

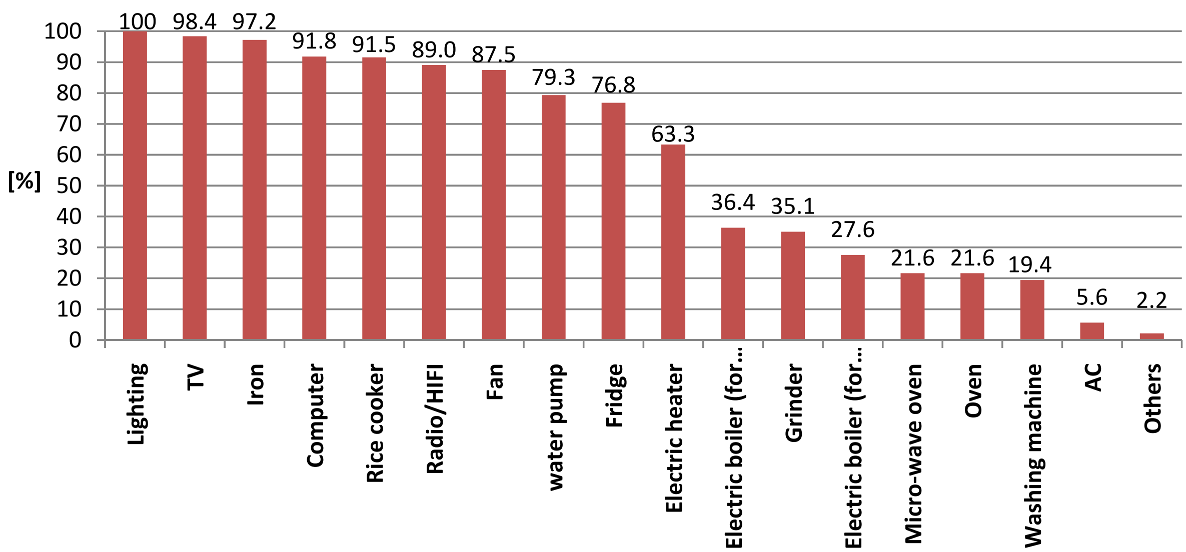


Figure 5-13: Type of electric appliances used by the households (Domestic users).

This shows that, for this particular urbanised group of the society, domestic economies have become highly electrified and a good number of activities nowadays depend on electricity.

<u>Question 4</u> is complementary to question 3, it asks people to list the various electric appliances they use, giving them a priority order that expresses their importance. The result presented below is obtained by aggregating only the first three priorities of each list, given a factor 1 to priority number 1, a factor 0.80 to priority number 2 and a factor 0.50 to priority number 3. Lighting clearly appears to be the most important service provided by electricity, distantly followed by computer, television, water pump and rice cooker. All other uses can be considered of minimal importance by the specific category of users. It is interesting to notice that those considered as most important uses (lighting, computer, television and water pumps) are fully compatible with a generation made by solar PV systems.

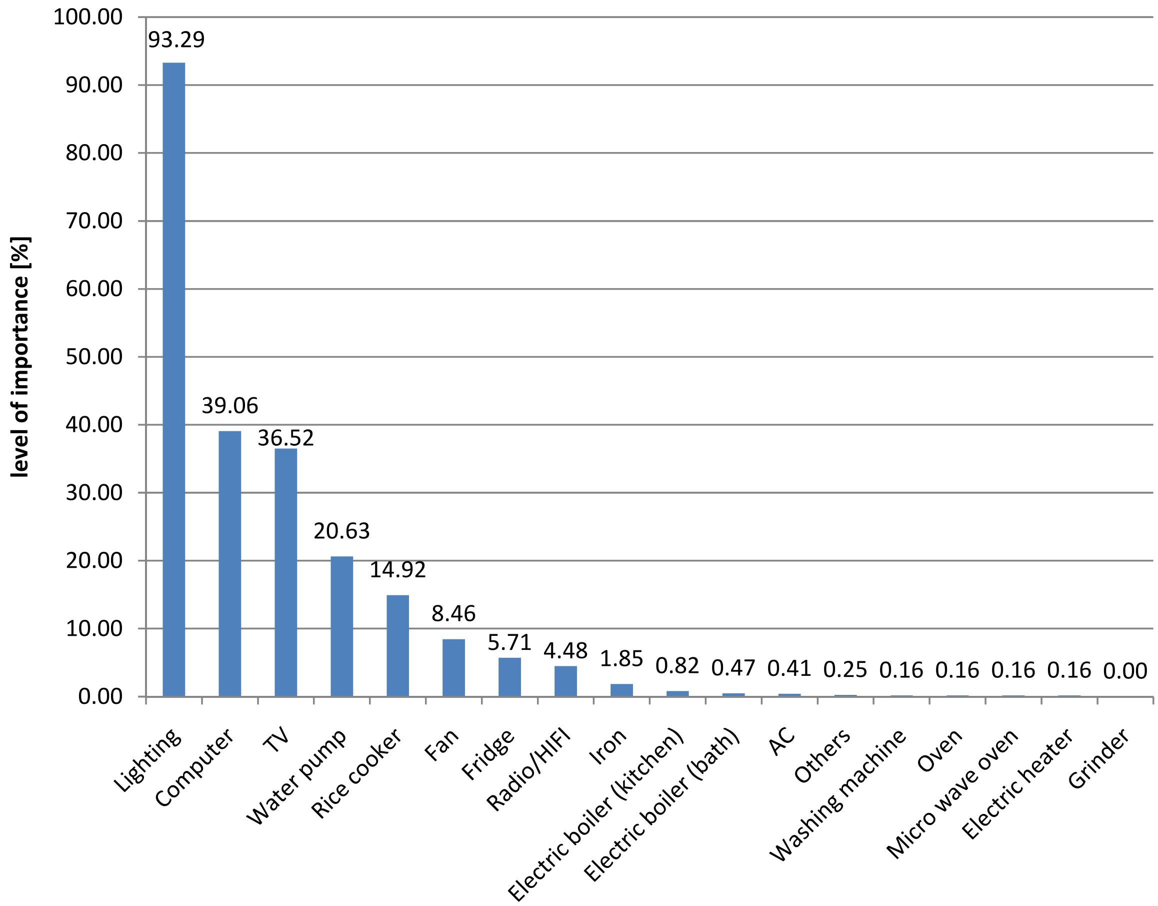


Figure 5-14: Priorities of use of the various types of electric appliances (Domestic users).

Question 5 is about what people do with their roof surface. It appears that about 70% of them use the roof as an outdoor area for enjoying the sun, about 50% for washing clothes, about 30% for social gatherings, about 28% for other outdoor works and 15% for various other activities.

Question 6 looks at the average roof surface of the buildings under inquiry. It appears that more than forty percent (40%) of the roofs have a surface between 50 and 100 [m^2], most of the other roofs have surfaces of about 15 [m^2].

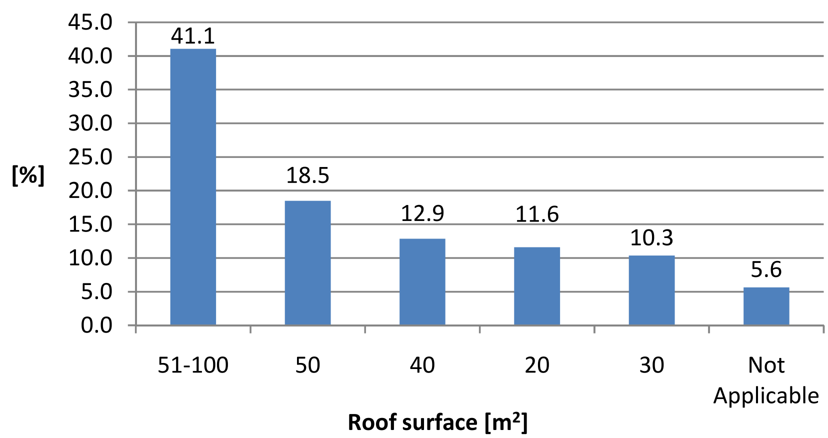


Figure 5-15: Roof surfaces of the buildings under inquiry (Domestic users).

<u>Question 7</u> *If you were to receive compensation for the use of space, how many square meters of roof space would you agree to leave for PV modules installation?* Most of the available roof surfaces are about twenty five (25) square meters and about five percent (5%) of them present available surfaces of fifty to hundred (50-100) square meters.

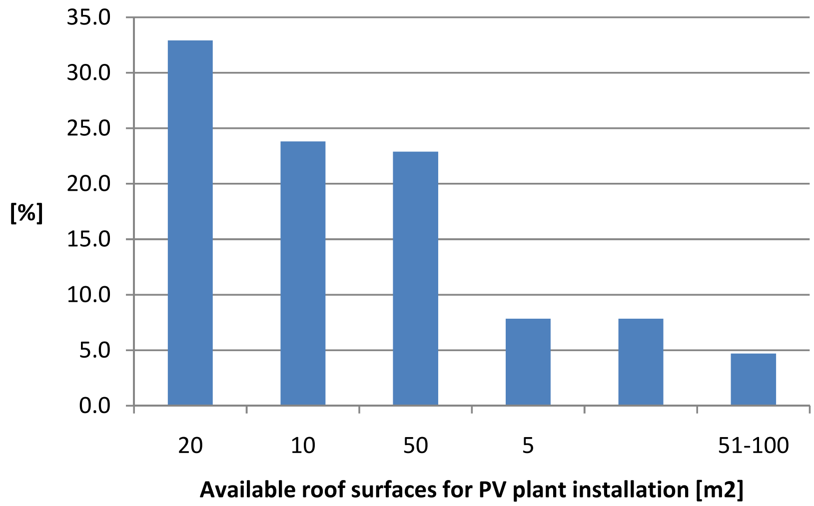
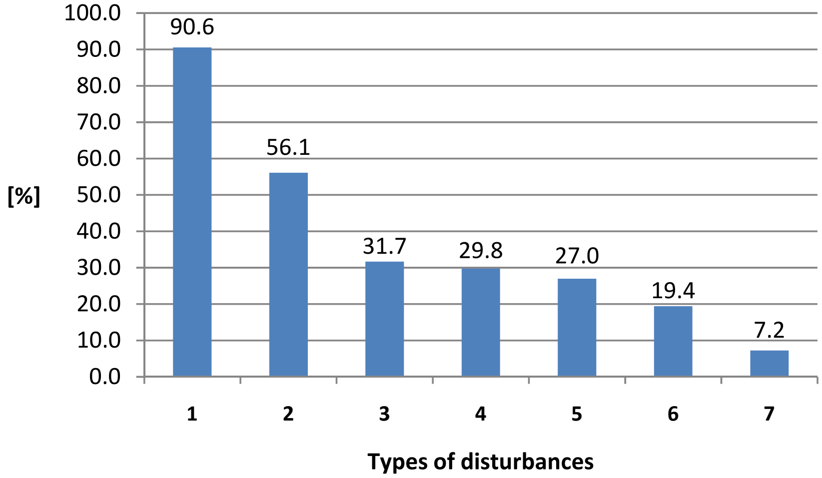


Figure 5-16: Available roof surfaces for PV plants installation.

<u>Question 8</u> *If you had a "cluster" solar PV system installed on your roof (which produces power not only to your house but to a group of neighbourhood houses), would you prefer to give access to the roof to external staff for regular cleaning of the modules or would you prefer doing this work with your own means/staff?* Here the responses of the owners are divided nearly equally between both options.

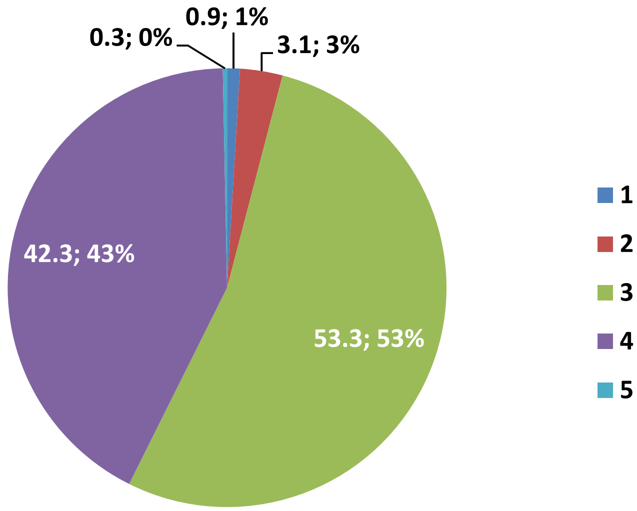
<u>Question 9</u> *In what ways do the load shedding periods affect your daily life?* For more than 90% of the families, the most disturbing effect is on education and study activities. This is explained by the lack of lighting in the evening. The second important disturbance (56.1%) concerns water supply. In fact, many households have their own well from which they pump the water to fill tanks placed on top of their roofs daily; long interruptions in power supply can result in incomplete filling and lack of water. With more than thirty percent, the diminution of work capacity and income is also a serious issue that can be linked with the difficulties in running computers as well as other electrical equipments and light. Food storage is equally perceived as an important problem, mainly due to the irregular functioning of fridges. About twenty percent of the people also express disturbances in social activities that can be due to the lack of lighting and leisure equipments such as music or movie players for gatherings. Risks linked with health hazards such as depression are considered serious by about one fifth of the households.



1 Disturbance of education and study activities
2 Disturbance of water supply
3 Loss of work capacity and diminution of income
4 Difficulties in food storage
5 Disturbance of social activities
6 Health hazards
7 Others

Figure 5-17: Disturbances in daily life due to load shedding periods.

Question 10 *What importance do you give to the issue of sustainable and clean energy for the future of Nepal?* A very marginal number of households (1%) do not consider the issue important at all. About three percent (3%) thinks that it might be important but that they can't do anything to improve or mitigate the situation. More than half of the people (53%) consider the issue to be important, they would like to do something but do not know what to do and how to do it. More than forty percent (43%) are convinced of the importance of the issue and already do something to improve the situation. These results demonstrate that there is a very strong consensus on the importance of the issue (96% of the people think it is important). It also reveals that the majority of those who would like to take action do not know what to do or how. The need for increasing the access to information and general communication on possible actions that citizens can take to improve the sustainability of the energy sector in the country is evident.



1. I do not care, it is not important at all for me
2. It may be important but anyway I cannot do anything to change the way it is
3. I think it is important, I would like to do something to improve the situation but I do not know what and how
4. I am convinced that it is important and I personally do something to improve the situation (I try to save energy, I look for alternative energy solutions, I discuss the matter with my friends and colleagues and search information in order to know better what are the possibilities for energy savings, I teach my children to save energy and explain them why,…)
5. No answer

Figure 5-18: The importance that households give to the issue of sustainable and clean energy for the future of Nepal.

5.6 Industrial and service sectors' point of view

In order to draw a representative point of view of potential users of PV grid-connected technology among the industry and service sector in Nepal, a survey was conducted through structured interviews with a selected group of 54 companies. The questionnaire (annex 1) includes inquiries about the type of industry/service, the way they manage power supply during load shedding periods, the willingness to pay for full time and reliable power supply, the type of building occupation (rented or owned), the possibilities of using space on the roof (including dimensions and possible use for community equipment) and finally, about the importance that the companies give to the issue of sustainable and clean energy for the future of Nepal.

Various companies, ranging from Cyber Cafés to Radio Broadcasters and schools were interviewed. All of these industries are at risk with the energy crisis they are presently bearing. The graph below shows the types of companies that were interviewed.

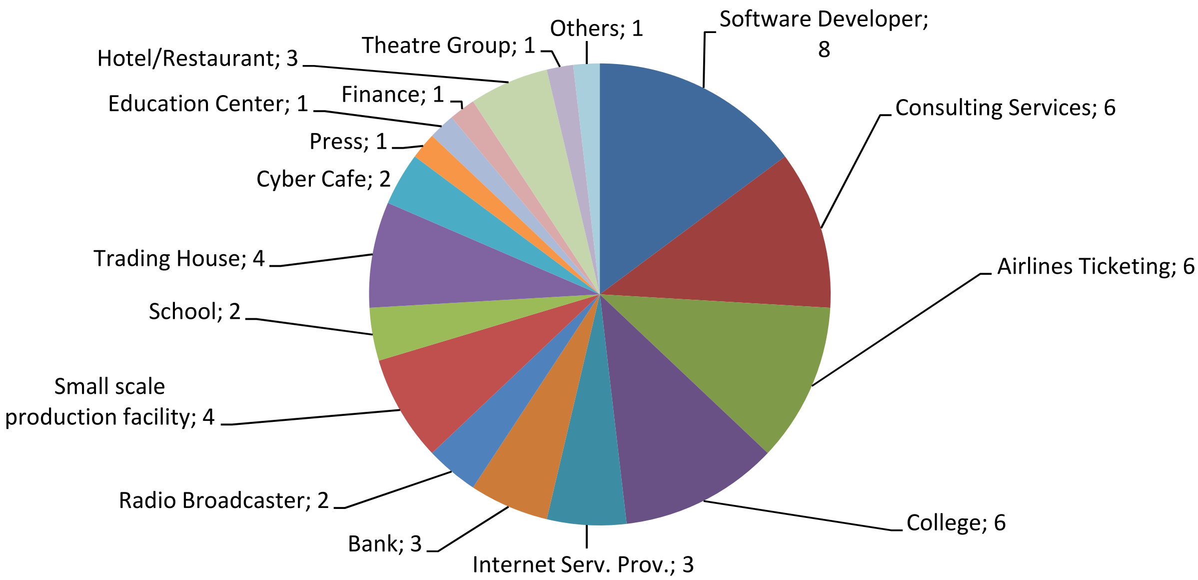


Figure 5-19: Type of companies that were interviewed as potential users of grid-connected PV technology.

Regarding the way companies manage power supply during load shedding periods, those with economic capacity have been using various means for electricity production. The main popular options are diesel-run generators (45%) and inverter-battery systems (38%). The common use of diesel run generators can be credited to the low price of diesel, and the use of inverter-battery systems can be explained by the low maintenance costs and easy availability. Solar PV-battery systems are used moderately (5%), probably because of the relatively high investment cost. LPG and kerosene-run generators (2%, respectively 1%) are used only marginally because they are more expensive to run than diesel generators. The industries with a small scale production and lesser capital were discovered to deal with the inconvenience and wait for better times. For some of them, this can mean they have to close the business or stop activities temporarily. The graph below presents the detail of the means used during load shedding periods.
The costs of generation of the various options are estimated to be:

- Diesel generator: about 30 [NPR/kWh] *size (industry.)*
- Petrol generator: about 40 [NPR/kWh] *size (industry.)*
- LPG generator: about 40 [NPR/kWh] *size (industry.)*

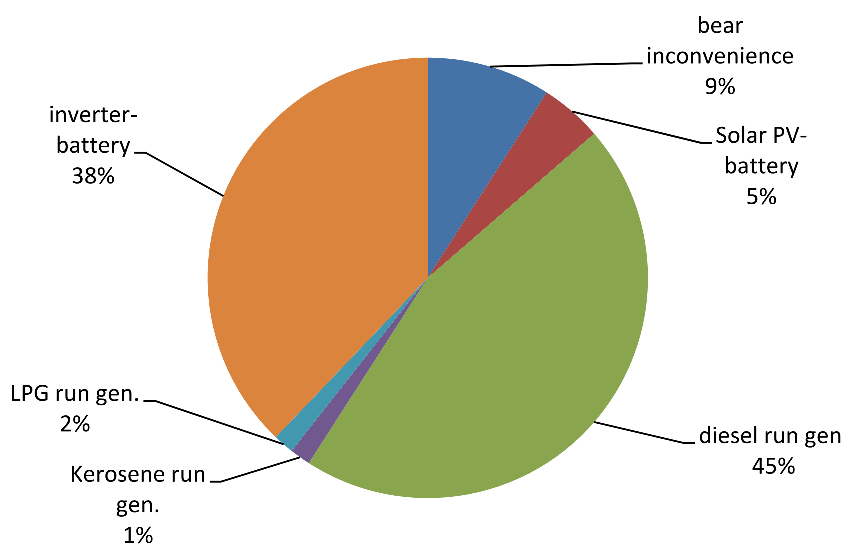


Figure 5-20: Means used by industries during load shedding periods.

The next question is: *How much is your company ready to pay for a reliable power supply for 24 hours/7 days?* 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 to a maximum of approx. 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) declared to be ready to pay 50 [NPR/kWh] and 2% (consulting service) even 60 [NPR/kWh]. These results are presented in the graph below.

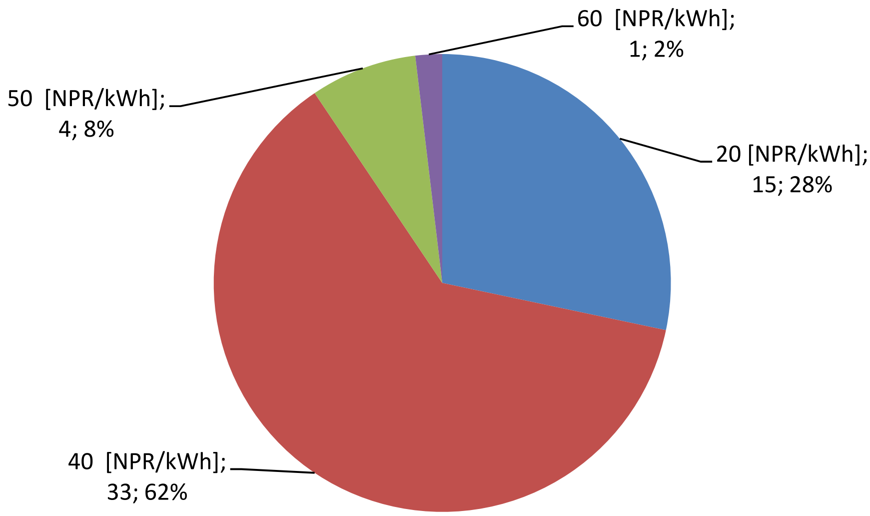
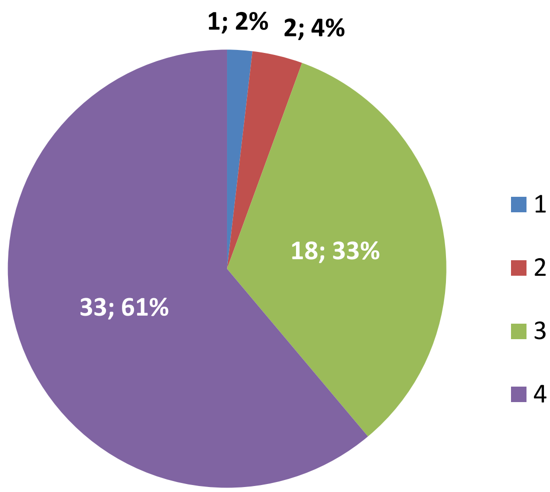


Figure 5-21: Number of companies willing to pay specific rates for 24/7 power supply.

In urban areas, PV systems are generally mounted and fixed on the roof of buildings. This makes it very important to consider the issue of the property of a PV plant, which might be separate from the building's property. It appears that a large majority of industries (around 70%) are operating and running in rented buildings, and that most of these have access to the space available on the roof and the ground of the building. The ground spaces were generally used for parking and other uses. Meanwhile, the rooftops were usually free, except for the presence of solar water heaters or water tanks. The average roof surface is about 100 m^2 and varies from 20 to 500 m^2. The average surface that would be available for the installation of a PV plant is about 35 [m^2] and varies from 5 to 100 m^2. Generally, the industries were ready to provide around 20% - 65% of the free space on roofs to lease for PV modules installation. Some of them (those having landlords, those having no free space and, those who would need legal permission to access the roof) couldn't discuss this matter. Some though were even ready to provide all the available free area for the purpose. Regarding the maintenance of the PV modules, half of them preferred external staff/company for maintenance of the solar PV system, while the other half would rather do it themselves.

The last question of the interview: *What importance does your company give to the issue of sustainable and clean energy for the future of Nepal?*
The responses, as represented in the graph below, express a clear conviction about the importance of the issue. In fact, sixty one percent (61%) of the companies agreed and said to be already acting to improve the situation. One third (33%) of the companies recognizes the importance of the issue and would be ready to take action but they do not know how. Only two companies think that it is important but that they cannot do anything. Only one company claims not to care about the issue at all. This shows that most of the industries have good intentions towards a more sustainable development, but that an important number of them lack information concerning ways to act and how to participate.



1. It does not care, it is not important at all for the company
2. It might be important but anyway we cannot do anything to change the way it is
3. We think it is important, we would like to do something to improve the situation but we do not know what and how
4. We are convinced that it is important and the company should do something to improve the situation (try to save energy, look for alternative energy solutions, discuss the matter with friends and colleagues, search information in order to know better what are the possibilities for energy savings, instruct the employees on energy saving measures at work)

Figure 5-22: The importance the companies give to the issue of sustainable and clean energy for the future of Nepal.

6 Feasibility analysis

6.1 Technical feasibility

The technical possibility of realizing a grid-connected PV system includes aspects dealing with both planning and technical characterization as well as the availability of components that satisfy its characteristics (grid, inverter, etc.).

6.1.1 Climatic condition

With about 300 days of sunshine per year in most parts of the country, an average of eight hours of light per day, and being situated on the ideal 30° North “solar belt”, Nepal presents very good conditions for the use of solar power.
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.
Only monthly data on a ten-year average are available. Data measured by RIDS-Nepal refer to the 2005-2006 period.

For this study, only the urban areas of Kathmandu valley were considered, it was thus not necessary to calculate the horizon so as to assess shadows generated by hills.

The seasonal variations in intercepted solar irradiation in the Kathmandu valley, Nepal, are, unlike in European countries, easily predictable. Furthermore, ‘climatic risks’ such as hail, strong winds, tornados etc. are very rare and thus do not need to be considered in the present study.
The difference between NASA data and the data measured by RIDS-Nepal in 2004-2005 is only **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 therefore give realistic results for the final yield of the customer’s system. For a particularly conservative approach, NASA data should be employed. For the present study, Meteronorm data was used, with horizontal yearly irradiation value of **1950 [kWh/m2/year]**, a figure 70% higher than in southern Germany.
The optimal tilted angel for a maximal yearly irradiation derives from the theoretical 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 important presence of clouds and very high temperature, summer is the season when the least PV energy can be produced. An increased tilt of the modules (compared to the theoretical 30°) will globally add to the productivity over the year.
The change of orientation (azimuth) of the installation in respects of the South does not particularly affect annual production. A loss of only 3% of incident irradiation occurs by modifying the installation’s azimuth by 30°.

With a 30° tilted angle, a module receives a global irradiation of **2’224 [kWh/m²/year],** which corresponds to an increase of 12% if compared to a horizontal surface.
Two-axis global monthly solar irradiation is **2940 [kWh/m^2]**, that corresponds to an increase of 33.6% compared to irradiation on a horizontal surface and an increase of 24 % if compared to a fix 30° tilted surface, plus 130% compared to southern Germany. The high quantity of incident solar energy on a two-axis system could be beneficial for medium-large installations. The decrease in module costs however, makes this solution less interesting compared to a fixed system.

High annual irradiation allows for an optimal utilization of a grid-connected installation and, consequently, a significant reduction in electric energy production costs.

The required meteorological parameters for the dimensioning of a grid-connected solar PV installation consist primarily in the global irradiation on a tilted surface and the ambient temperature minima and maxima. The available meteorological data are sufficient for analyzing the energy efficiency of a PV plant. For a more detailed dimensioning of a grid-connected PV power plant, it would be necessary to access minute-based irradiance data from all over the country.

6.1.2 Public Grid condition

The Nepalese energy system has enormous potential, undeveloped resources. The potential for hydropower, for instance, is huge. However, the country's economic situation does not allow for adequate development thereof within the time limits imposed by the augmentation of power consumption.
The power system is a balance between production and consumption. Severely unbalanced situations cause changes in the frequency of the system and can therefore cause a system collapse. One way to save it from collapse is load shedding!
The main sources of power supply are: ROR hydro, PROR hydro, Seasonal storage hydro, Thermal Power plants, and Import from India.
During the wet season, the demand amounts to approx. 780MW, while production only reaches 620MW (at 100% capacity of the total installed power capacity). There is therefore a deficit of approx. 160MW. During the dry season, demand reaches 893MW (evening peak) while production only reaches 453 MW (at 100% capacity of the power plants able to run during the dry season). The deficit is approx. 440 MW. In particular during the dry season, both at the morning and evening peaks, as well as the rest of the day, there is a lack of production of approx. 50%.

In this context, PV production with its production peak during the mid-day hours would lower the daily energy lack.

One of the major problems for the realization of a grid-connected system in Nepal is whether the grid is available at the place of installation. In Kathmandu, scheduled interruptions (load shedding) vary from a minimum of 2 hours per day during the wet season to a maximum of 16 hours during dry season.
The load shedding hours do not necessarily correspond to solar PV production, but depend on various factors such as weather, location, production capacity, demand, etc.
An inverter in a grid-connected PV system is equipped with an islanding prevention system. In case of power failure, the inverter switches off automatically to prevent a potential dangerous situation on the grid. Therefore, an installation with an inverter for grid connection would be stopped from feeding any generated energy into the grid during load shedding, with a consequent production loss. This means that the energy potentially available could no longer contribute to compensating the lack of energy produced through hydro technology.
The first grid-connected PV installations will therefore be placed in locations where load shedding does not occur, such as in hospitals, NEA buildings, etc.
For other areas, it is possible to consider a pattern of grid-connected, feed-in PV systems combined with local energy accumulation/storage, for example thanks to batteries.
In this case, the solar energy produced during load shedding would go partly to local consumers, and partly to the local battery bank. The creation of such mini-grids needs more initial investment (see chapter 6.2).

Grid conditions required for AC interconnection:

- Voltage level should be the same as the grid, i.e. 220V at the load side in the case of Nepal.
- The frequency of PV power should be equal to existing grid frequency, i.e. 50 Hz in the case of Nepal.
- Phase sequences should match in case of 3 phase AC interconnection.
- Disturbance in the transmission signal due to harmonics should be kept to the acceptable minimum limits. This can be achieved with Pure Sine Wave Inverters.
- Voltage flicker should be avoided, i.e. frequency mismatching and operation of sudden heavy loads need to be avoided.
- Islanding problems should not be persistent, and the use of circuit breakers and directional relays in the interconnecting circuits are advisable.

Mean Grid Voltage by consumer was **209.6 V, ranging from 193 V to 222 V**

The average voltage measured in local households in Kathmandu shows that in some cases minimum grid voltages of less than 200 V are encountered.

6.1.3 Components availability

Modules:
In Nepal, 59 companies sell photovoltaic modules. Only 26 however are approved by the AEPC (Alternative Energy Promotion Center), and are therefore entitled to benefit from the Rural area subsidies for SHS. The survey carried out for this study was answered by 23 out of the 26 companies in Kathmandu approved by the AEPC.

The total amount of solar PV modules sold in 2008 was 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 49Wp, but the average power of sold modules was of approx. 30W. Therefore, the estimated installed power in Nepal in 2008 amounts to approx. 1.3 MW.
Globally, 7MW (of which 1.3MW only in the fiscal year 2008-2009) have been installed in Nepal. At present (end 2009), there are approx. 200'000 installed SHS in Nepal.

Solar PV Modules mean prize per watt: **292 NRs/W** (2.7 €/W) (November 2009)

PV modules import channels are available. The government (GoN) grants a reduced VAT of 2,5% for PV modules, which compares to the usual 13% for other electronic components. Nowadays the market is still limited to modules with multiples of 36 cells, which are ideal for the connection to regular 12V (or multiple) battery systems. For the grid-connected systems, modules with different numbers of cells are generally used, i.e. modules with 60 cells are very common in Europe.

Thin film modules aren’t widely in use yet, despite the fact that they have great potential for the hotter, tropical, low-altitude regions of Nepal, where they obtain better energy generation per watt over the course of the year, and where their purchase means cost savings.
The restrictions to import opportunities are essentially due to two reasons. In order to have access to the VAT reduction, it is necessary to meet the criteria set out in the NEPQA norm. Modules have to be submitted to additional national tests, even when they have already passed internationally accepted IEC tests. Measurements are carried out by the RETS. In particular, the module’s real power in outdoor conditions is measured.
With measurements for thin film modules, interpretation and extrapolation of results at standard conditions (STC) can be problematic. For this reason, the RETS laboratory capacity needs to be improved so as to allow an effective thin film module measurement, which can be compared to that of the major international test labs. Indeed, thin film modules are ideal for climates such as the Kathmandu valley, characterized by a high irradiance and medium high constant temperature, but low humidity.
The second limiting factor relates to the request enclosed in the NEPQA norm.

Certifications of PV modules

Normally, PV modules for grid-connected systems are certified to be compliant with IEC 61215 or 61646, and safety IEC61730-2 standards.

The certification is issued by a certification institution that is separate from the accredited test institution:
- it controls the test reports issued by the accredited test centre
- it is itself accredited ISO 45011
- It gives the certification stamp and number

The test report is issued by the accredited test centre:
- it carries out all tests according to the IEC standard required
- every test it is accredited ISO 17025

Within the AEPC NEPQA 2009, it is explicitly required that PV modules have IEC 61215 or IEC 61646 (for thin film) certification.
Unfortunately, NEPQA 2009 also requires the provision of the “full test report” of IEC tests. IEC test reports are not publishable both for reasons linked to ISO17025 accreditations of test laboratories, and because every test report also contains details concerning manufacturing, used materials etc., and every serious manufacturer will refuse to give its knowledge to his competitors!
Of course no serious manufacturer will give a non-certificated ISO 45011 body his test reports.
Every test report must contain how the module is made (an information held, of course, very confidential), in order to control if the specific module is the same during period of the certification (normally 5 years).

If NEPQA maintains these requirements, Nepal will have to face an import of very poor modules, produced by unserious manufacturers rather than reliable producers.
In no other country have the authorities established these kind of requests. IEC certification is a guarantee of production quality.

On-grid inverters

The market for inverters for grid-connection is still inexistent. Such a market can be achieved through normal local distributors. However, the inverters' set up has to be modified in order to respect the grid characteristics.

The battery chargers (from grid), batteries, and classic DC/AC (12Vdc/230Vac) inverters' markets are however well developed. The standard cost for standalone inverters is about 20NRs/VA.

6.1.4 Energy Production of a grid-connected PV system in Kathmandu, Nepal

Favourable climatic conditions allow an easily predictable, high, annual energy production.
Initially, the energy yield for two 10.26 kWp plants (one fixed at 30° and one on a two-axis system) was simulated. For the simulation, monthly Meteronorm data was used (horizontal yearly irradiation of 1950 [kWh/m^2/year]).

6.1.4.1 PV power plant in Kathmandu, south oriented and tilted at 30°

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

Normalised production (30° tilt) Yf ≅ 1'700 [kWh/kWp/year]

The same photovoltaic installation, mounted on a **two-axis sun tracker**, could produce 23MWh/year.
If the two-axis sun tracker mounted installation had 1MWp nominal power, it would produce 2300MWh/year.

Normalised production (two-axis sun tracker) Yf ≅ 2'300 [kWh/kWp/year]

PV characteristics:

PV module	Si-mono	Model	**TSM-190 D03**		
		Manufacturer	Trina Solar		
Number of PV modules		In series	27 modules	In parallel	2 strings
Total number of PV modules		Nb. modules	54	Unit Nom. Power	190 Wp
Array global power		Nominal (STC)	**10 kWp**	At operating cond.	9.5 kWp (50°C)
Array operating characteristics (50°C)		U mpp	624 V	I mpp	15 A
Total area		Module area	**71.1 m²**		

The 10.26kW system consists in a series of 27 in parallel modules connected to a central SOLARMAX 10kW inverter.

2x27 TSM190, 10kW, 30° in Kathmandu
Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	EOutInv	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	%	%
January	140.0	7.90	207.0	201.9	1827	1711	12.42	11.63
February	145.0	12.30	187.8	183.1	1625	1522	12.17	11.40
March	186.0	17.90	208.9	203.5	1773	1661	11.94	11.19
April	204.0	24.00	201.9	196.0	1670	1562	11.64	10.88
May	213.0	26.80	192.2	185.8	1569	1462	11.48	10.70
June	175.0	26.30	154.4	149.0	1264	1172	11.52	10.68
July	149.0	24.10	133.9	129.1	1099	1014	11.55	10.65
August	147.0	23.50	139.8	135.1	1153	1066	11.61	10.73
September	146.0	22.60	154.3	149.7	1285	1193	11.72	10.88
October	163.0	19.80	198.9	193.9	1680	1570	11.88	11.10
November	142.0	14.90	202.7	198.0	1748	1640	12.13	11.38
December	140.0	9.90	220.4	215.2	1936	1816	12.35	11.59
Year	1950.0	19.19	2202.4	2140.3	18630	17388	11.90	11.11

Table 6-1: Balance and main results of a south oriented, 30° tilted, 10.3kWp PV power plant in Kathmandu.

In comparison, in Lugano (Switzerland) the energy production is 1.55 times lower. This means that the energy cost will be 1.55 times lower than the cost in Switzerland.
During the monsoon period (June to September) the monthly production decreases significantly. During the rest of the year however, it is fairly constant, with a maximum in December-January.

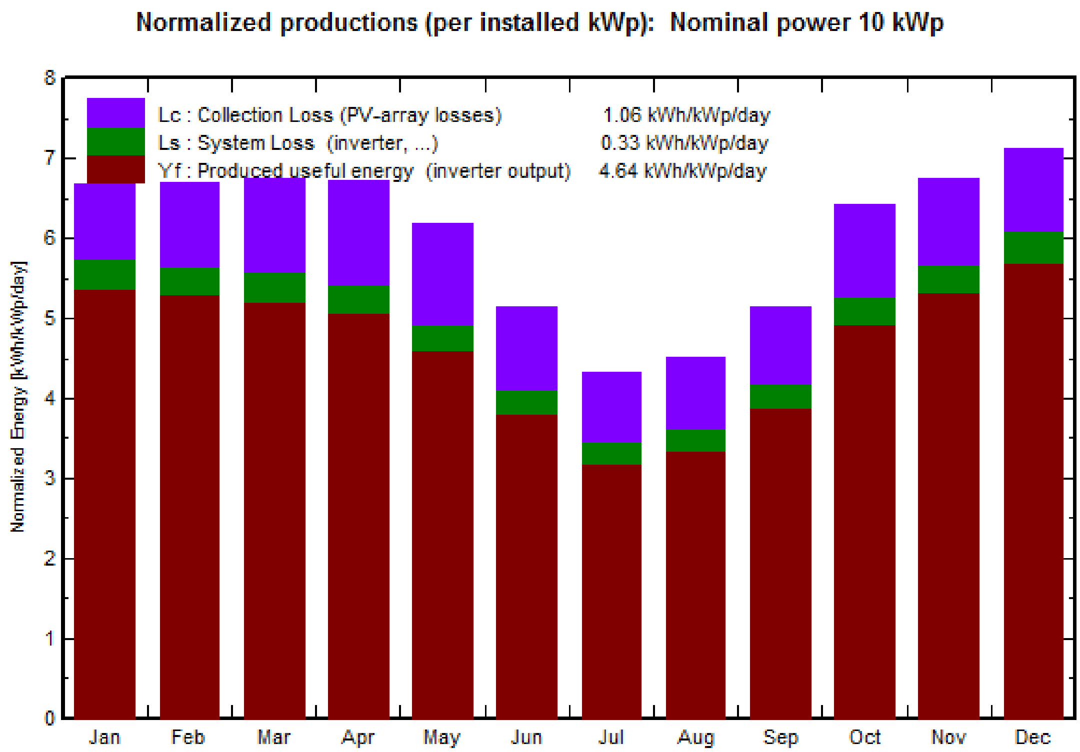


Figure 6-1: Normalised energy productions of a south oriented, 30° tilted, 10.3kWp PV power plant in Kathmandu.

Performance Ratio: **PR = 0.77**

The yearly performance ratio (PR) of 77% is quite high and corresponds to the functioning of a standard plant in central European climatic conditions. Considering the fact that ambient temperatures are higher in Kathmandu than in Europe (and consequently, so is the module's temperature), and considering also the fact that the inverter used for the example is of medium quality and efficiency, the resulting PR is very good.

PV Array loss factors

Heat Loss Factor	ko (const)	25.7 W/m²K	kv (wind)	0.0 W/m²K / m/s
=> Nominal Oper. Coll. Temp. (800 W/m², Tamb=20°C, wind 1 m/s)			NOCT	48 °C
Wiring Ohmic Loss	Global array res.	1349.8 mOhm	Loss Fraction	3.0 % at STC
Serie Diode Loss	Voltage Drop	0.7 V	Loss Fraction	0.1 % at STC
Module Quality Loss			Loss Fraction	3.0 %
Module Mismatch Losses			Loss Fraction	2.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1-bo (1/cos i - 1)	bo Parameter	0.05

For the simulation, standard values concerning the PV field losses were maintained. A periodical cleaning of the modules during dry season is supposed. Therefore, the effects of dust and pollution are not considered in the simulation.

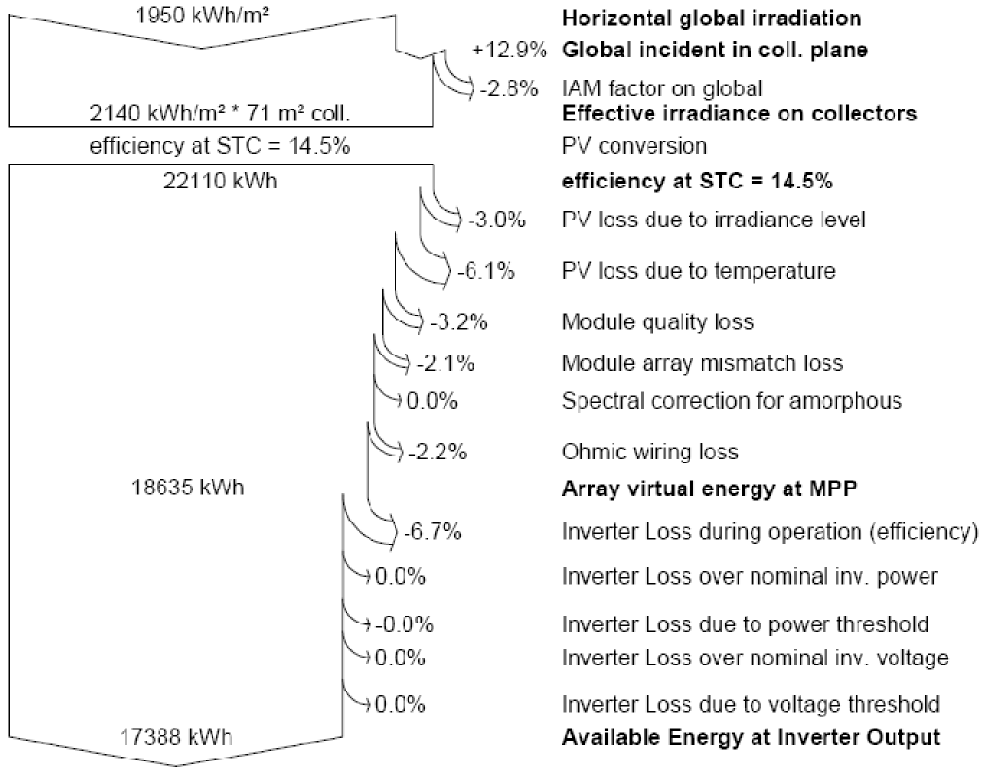


Figure 6-2: Loss diagram over the whole year in a grid-connected, 10.3kW system in Kathmandu, tilted at 30°.

The greatest loss (-6.1%) are due to the module's high temperature. Therefore, particular attention must be given to a good natural ventilation of the modules mounted on the array.

It is possible to further improve the performance ratio by using an inverter with a higher weighted ratio (see chapter 4.2.2, Nepalese inverter weighted efficiency).

6.1.4.2 PV power plant in Kathmandu, two-axis sun tracker

An identical system but built on a two-axis sun tracker allows a higher yield for the same power, but at a higher cost and maintenance. Consequently, such a system is indicated for medium and big size systems.

Energy generation reaches 2'315 kWh/kWp, which is **26%** higher than in a system on a south oriented, 30° tilted, fixed array structure.

	GlobHor	T Amb	GlobInc	GlobEff	EArray	EOutInv	EffArrR	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	%	%
January	140.0	7.90	279.5	277.1	2527	2367	12.72	11.91
February	145.0	12.30	248.7	246.1	2207	2070	12.49	11.71
March	186.0	17.90	276.7	273.6	2409	2260	12.25	11.49
April	204.0	24.00	278.0	274.6	2368	2222	11.98	11.24
May	213.0	26.80	275.2	271.4	2318	2173	11.85	11.10
June	175.0	26.30	204.5	200.5	1719	1606	11.83	11.05
July	149.0	24.10	171.5	167.8	1446	1345	11.85	11.03
August	147.0	23.50	173.9	170.3	1470	1367	11.89	11.06
September	146.0	22.60	196.2	193.1	1678	1567	12.03	11.23
October	163.0	19.80	261.1	258.3	2259	2117	12.17	11.40
November	142.0	14.90	268.6	266.2	2366	2218	12.39	11.61
December	140.0	9.90	302.7	300.4	2713	2537	12.61	11.79
Year	1950.0	19.19	2936.8	2899.4	25479	23848	12.20	11.42

Table 6-2: Balance and main results of a 10.26 kWp PV system in Kathmandu, with two-axis sun tracker.

The Performance Ratio of the two-axis (PR = 0.776) system varies little compared to a fixed system using the same components. It can be increased using an inverter with a higher yield particularly at high power.

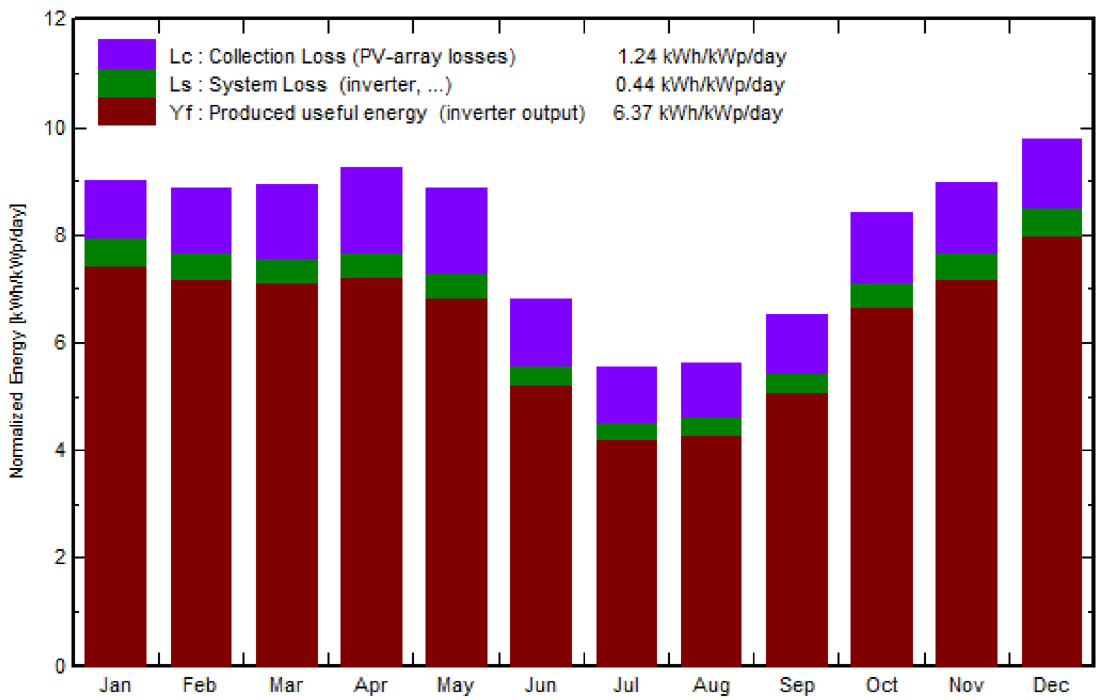


Figure 6-3: Normalised energy productions of a 10.26 kWp system in Kathmandu, with two-axis tracking.

The monthly distribution of production of the two-axis tracking system is more uniform and the decrease during the first months is less important than with the fixed system.

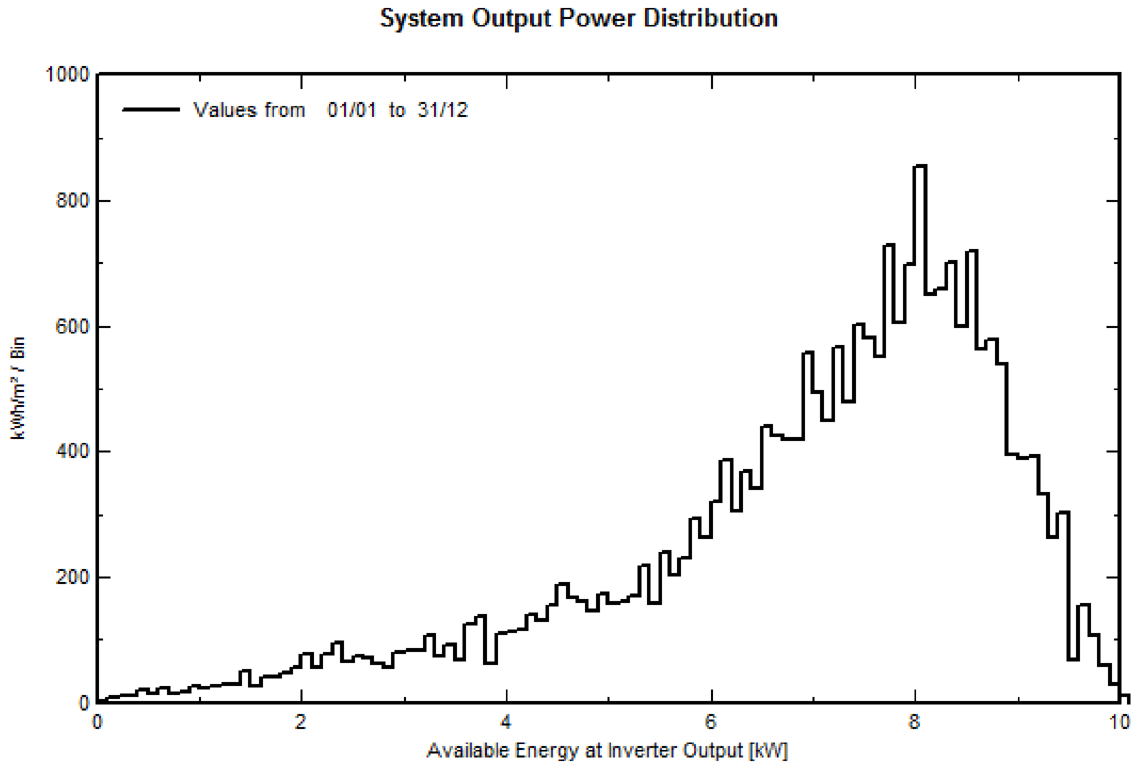


Figure 6-4: System output power distribution.

The array power distribution is concentrated between 65% and 100% of the module's power. Consequently, the chosen inverter output must be particularly high in this particular power band. The generated power will be more constant during the day in comparison with a fixed installation, evenly distributing the produced energy throughout the day.

The PV plant's voltage will rarely exceed the nominal voltage because of the high ambient temperature throughout the year.

6.1.5 Educational

The lack of competent technicians in the grid-connected sector can be a major issue for the promotion of on-grid installations. Basic technical knowledge for SHS is taught in the Solar Electric Technician Level - I and II courses. This basic training should be made complete by the addition of a specific training for grid-connected PV systems, including technical details on grid-connected inverters, dimensioning, installation, protection and connection to the grid.
It is also necessary to promote knowledge on grid-connected solar PV energy feed-in systems within Universities, so as to train competent future planners.

6.1.6 Summary of technical feasibility

- The yearly intercepted solar irradiation in Nepal is easily predictable.
- Climatic risks such as hail, strong winds, tornados etc. are very rare and thus don't need to be considered.
- Horizontal yearly irradiation in KTM is high: **1950 [kWh/m^2/year].**
- With an optimal 30° tilted angle, a solar PV module receives a global irradiation of 2'224 [kWh/m^2/year]. Thus the return on investment time of a standard grid-connected plant will be about half what it is under central European conditions.
- Two-axis annual intercepted global solar irradiation is 2940 [kWh/m^2]. The high incident solar energy intercepted with a two-axis system could be beneficial for medium-large solar PV installations. However, the decrease in module costs makes this solution less interesting.
- Dust and pollution in the KTM region require regular cleaning of PV modules.
- Standard solar PV modules for SHS are available in Nepal. There is a high probability that the cost of solar PV modules will reduce considerably with time, it should therefore be checked continually.
- NEPQA 2009 requires that the "full test report" of IEC tests for imported solar PV modules be provided, a condition for obtaining VAT reduction (2.5% instead of 13%). This condition is contrary to the practice in other countries of the world. In fact, full test reports of this kind contain confidential information on modules' construction, and thus the main producers most certainly will not provide these reports to a non-certified ISO45011 institution.
- Thin film solar PV modules are complex, and the measurement of their characteristics requires specific equipment and knowhow that are not yet available in Nepal. RETS laboratory should receive support in this domain in order to allow this technology to be adopted in Nepal. If the testing of thin film modules is not made possible, these would be penalized because they could not benefit from VAT reduction.
- Inverters for the grid-connection of solar PV plants are not yet available in Nepal. The setup parameters of currently available inverters would need to be adapted to the parameters of the Nepalese grid. The adaptation of such parameters can be easily realized by the importers of the inverters.
- During the dry season in particular (February – June), both during morning and evening peak hours as well as during off-peak hours, the grid cannot provide the required energy. The lack of power is approx. 50%. Solar PV arrays, with their main power production peak during the mid-day hours, could minimize the daily energy shortages significantly.
- Since load shedding affects the capacity of a grid-connected solar PV installation to deliver power to the grid, the first installations of this kind should be placed in locations where the phenomenon does not occur, such as hospitals, NEA buildings, etc. For other areas, it is possible to consider systems that combine grid-connected PV systems with a local energy accumulation/storage facility, such as e.g. batteries.
- The simulations carried out in this study demonstrate that the productivity of grid-connected solar PV plants in the Kathmandu Valley would be high.
- There is no specific professional training or course on grid-connected solar PV systems. It is necessary to promote practical knowledge on solar PV energy grid-connected, feed-in systems. Promotion should also take place in universities, so as to train competent planners and installers for the future.

6.2 Economic feasibility

The socio-economic importance of access to electricity.
Access to electricity has positive impacts on the lives of the people. Studies in other countries have emphasized that having access to electricity is beneficial for childrens' education because it facilitates reading during the evening and in the early morning hours. In addition, adults also tend to read more when their household has electricity, something especially true for women. Electricity also enables greater communication in the form of radio and television. This gives people in rural areas access to knowledge and information that would not be available otherwise. Depending on the conditions in local communities, electricity can also lead to an increase in rural productivity and development. The most immediate impact of electricity on local rural enterprises is that grain mills switch from human and diesel energy to electricity. Electricity can often lead artisans to work more in the evening. Small businesses such as retail shops also depend on electricity for lighting and refrigeration. Electricity programmes often complement health programmes by providing refrigeration for medical supplies. For productive uses, as indicated in an example from Peru, it has been observed that programmes involving complementary social infrastructures have a greater impact on the people than private domestic programmes.

Comparative analysis of various technologies.
In the framework of this study, 7 technological options have been compared with regard to their energy production characteristics and costs. The comparison was carried out on technologies that can presently be found on the market:

1. SHS (Solar Home System) – 1kWp PV modules, 800Ah Batteries
2. inverter with 600Ah of batteries,
3. inverter with only 100Ah of batteries,
4. petrol genset of low quality and
5. petrol genset of high quality,
6. grid-connected photovoltaic installation with backup system. – 1kWp PV modules, 800Ah Batteries
7. grid-connected photovoltaic installation without backup system (standard grid-connected system). 1kWp PV modules

For the comparison, the following general initial conditions have been established:

- Daily consumption of the household: **5kWh/day**.
- **Constant load** during the day.
- Avg. daily load shedding throughout the year: **7 hours.**
- Investment **paid in cash.**
- Grid Energy cost per unit: **9.9 NPR/kWh**.
- **VAT included** (PV modules: 2.5%; others: 13%).

The daily energy consumption depends highly on the economic conditions of the household. In the present study we have considered an average consumption of 5 kWh/day, corresponding to a middle-upper class household.
In the case of the SHS, the amount of available daily energy will be minor. It would be possible to increase it through the integration of a battery charger but the production of solar energy would remain limited anyway. In the present study such a case was not considered.
In the simulations, a constant load was considered. However, a more detailed simulation would allow more accurate distinguishing of the impact of load variations according to the time of the day and to the solar PV system's energy production.
According to the location, the duration and time schedule of the load shedding varies. It is thus not possible to generalize the impact of load shedding in detail. On an average it is currently (2009 – 2010) of about 7 hours a day throughout the year.
For high initial investment installations (such as PV systems), the possibility of paying in cash drastically limits the negative effect of high interest rates. The economic capacity of the category of people considered in the study is above the average and thus cash payments for the investments have been considered.
The solar PV system's annual cost calculation includes the initial investment (solar PV modules, mounting frame, batteries, regulator or inverter, settings – wiring, safety MCB, connector - box - bus bar – earth, transport and assembly, etc.), as well as maintenance and replacement costs (for inverters and batteries) over a 25 years life time of the plant, equaling the life span of most available, good quality solar PV modules.

6.2.1 Energy production comparison

The impact on the grid of the different technologies used and analyzed can be observed in Figure 6-5.
The yellow bars represent the **energy produced** by the different technologies, while the green bars represent the **energy fed** into the grid. For both grid-connected PV systems all the produced energy is fed into the grid.

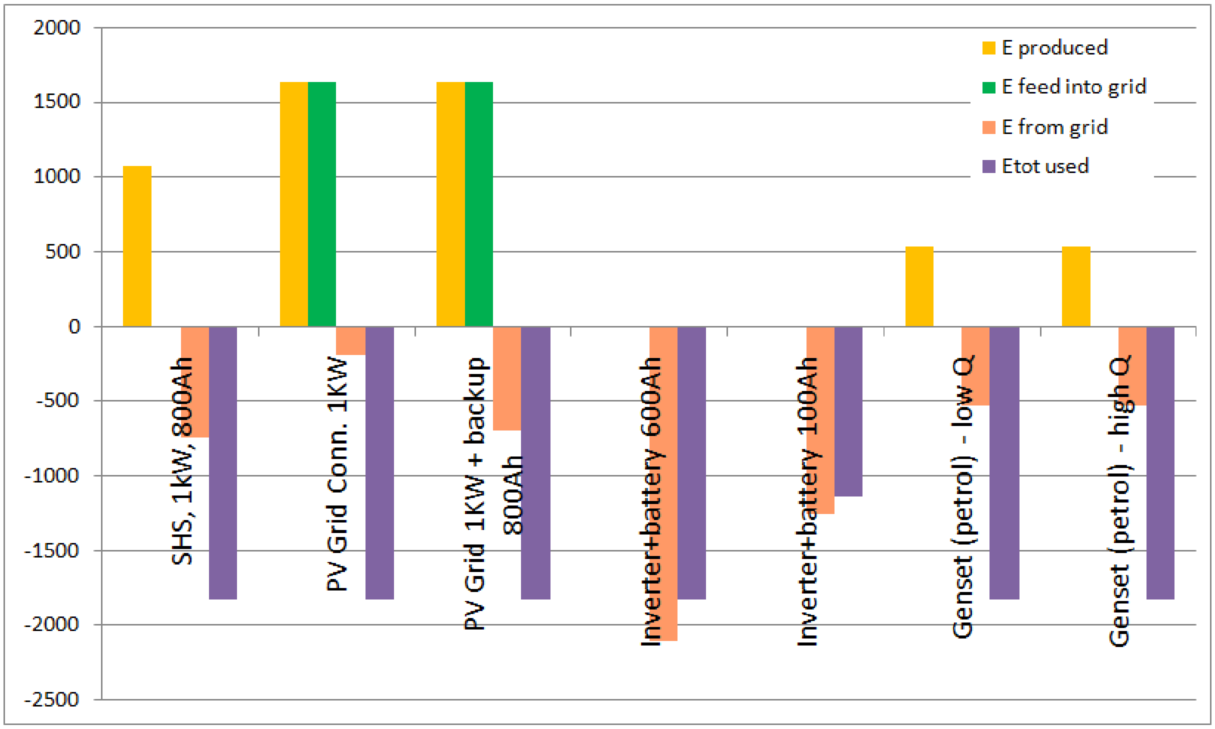


Figure 6-5: yearly energy [kWh/year] produced by the various systems, injected in to the grid, consumed from the grid and total energy used by the systems.

On the negative axe of Figure 6-5, the pink bars represent the difference between the energy fed into the grid and the energy imported from the grid. **Photovoltaic grid-connected systems are the only technologies sustaining the grid. On the contrary, inverter plus battery systems are the only configuration that worsens the grid condition, consuming more than the total used energy due to their poor overall efficiency.** This is due to the fact that they do not produce energy but need energy to compensate for the losses in the backup system. Also, if the battery is too small, the available energy for sustaining the family household needs will be insufficient and thus the family's living standard will decrease.

In the case of solar home systems (SHS), a fix amount of energy consumption (3kWh/day) is considered. If more energy is demanded, it is provided by the grid.
In the case of a genset, the system has no interaction with the grid. It produces only the energy needed during the load shedding period.

6.2.2 Cost Comparison

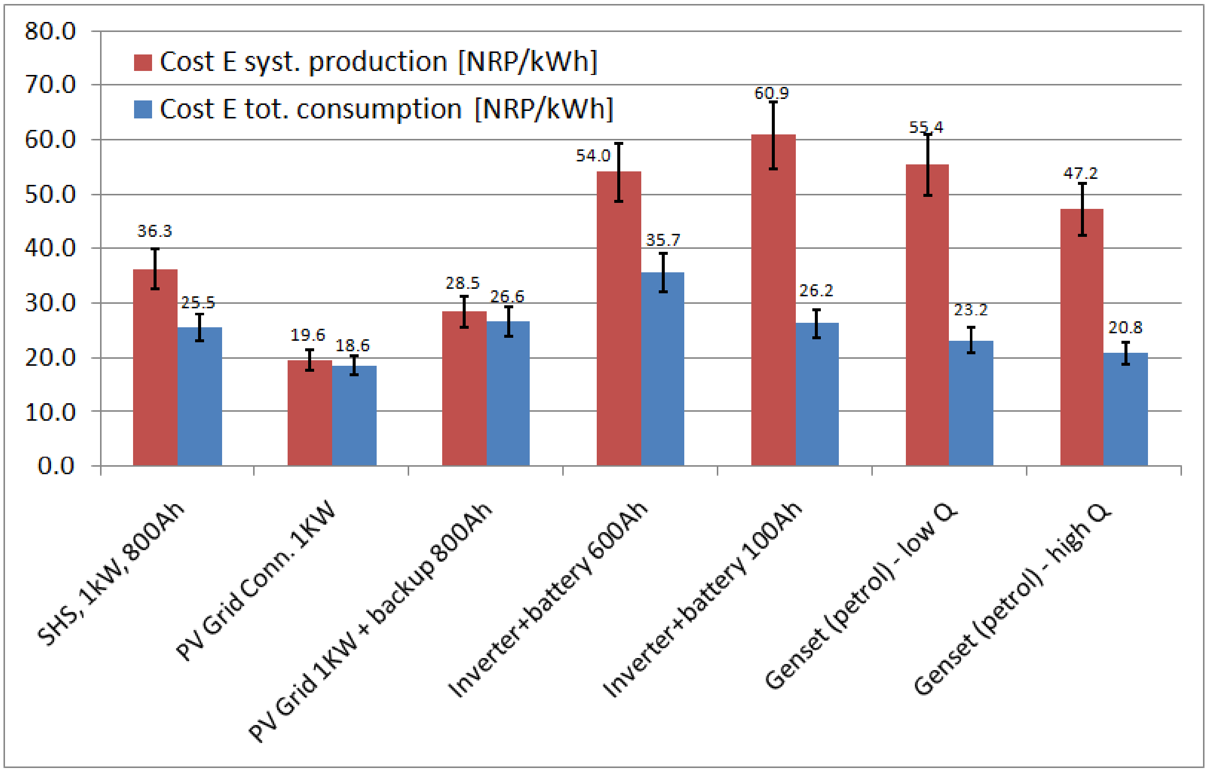


Figure 6-6: Cost of the energy produced by the systems, and cost of the energy used by the household (Esystem + Egrid), with investment: 100% cash.

Figure 6-6 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 (energy produced by the system + energy from the grid).
It is clearly visible that the 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 lower, 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 economical 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, the 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.
Kulekhani I , Kulekhani II, Hetauda Diesel and Duhabi Multifuel are meant to supply the peaking power.

The Clean Energy Development Bank (CEDB) would be ready to provide advantageous financing conditions for PV grid-connected technology (ca. 9% interest rate instead of 11%).
If we consider an investment financed at 50% with a 9% interest rate, and at 50% with cash, the cost of produced energy (in red in figure 6.7) of the systems with high initial investments would be higher. In the case of the grid-connected system, the cost would however remain the most competitive compared to other solutions

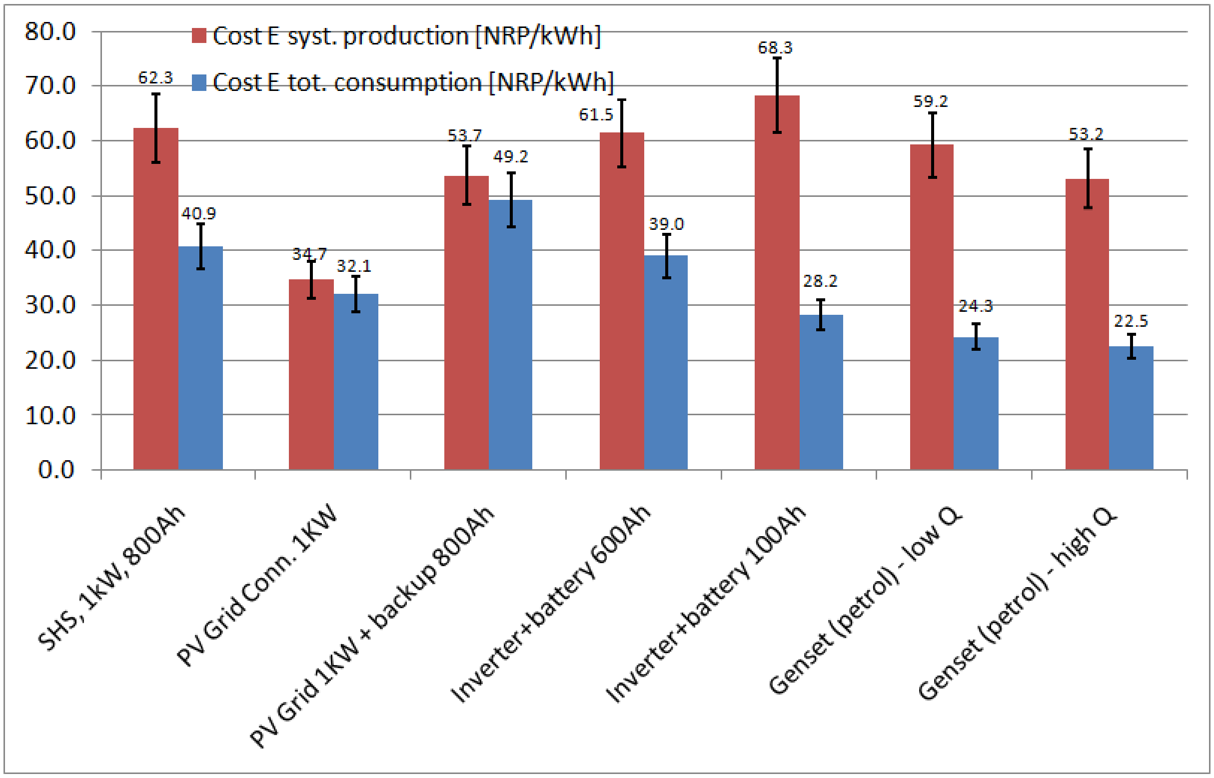


Figure 6-7: Cost of the energy produced by the systems, and cost of the energy used by the household (Esystem + Egrid), with investment: 50% cash, 50% loan at 9%.

Figure 6-7 presents the costs considering an investment with 50% in cash and 50% with a facilitating rate (9%) bank loan.
In spite of the unfavourable rates for an installation requiring a high initial investment, the energy produced by a PV installation is competitive. If the period of load shedding (at present of 7h/d) were to increase, as officially expected, the cost of the total used energy would become even more unfavourable for non solar technologies. In fact, an increase in load shedding duration would economically favour the options using grid-connected PV technologies, which would also support the grid with an additional input of energy. However, it would be necessary to consider an increased backup system (more batteries). If, in the contrary, the load shedding duration were to be reduced, then the solutions with low initial investment but with higher total cost would become more favourable (inverter + battery, genset) because the main energy used would be from the grid, which has the lowest cost (9 NRs/kWh). However, in this case as well, the option with inverter + battery would be the worst in terms of its increased load demand from the grid because of the system's high losses.

6.2.3 Summary on cost feasibility

- With solar PV plants (SHS and grid-connected systems), the amount of energy produced is (would be) high in the context of Nepal. In the case of grid-connected systems, the energy is fed into the grid, and thus contributes to improving the energy availability in the country, which in turn also contributes to the improvement of the economy and employment situation.
- In the case of genset systems, the energy is produced only during the load shedding period and for immediate energy demands. The fuel must be imported, which aggravates the already poor economic condition of the users and the country. Besides, diesel supply is very insecure in Nepal, and the way costs will evolve is uncertain.
- In the case of inverter-batteries systems (currently the most commonly used technology to compensate for the loss of power during load shedding), no additional energy is produced to be fed into the grid. On the contrary, the energy required to charge the battery bank (considering the low efficiency of batteries and the inverter) has to be taken from the grid, thus worsening the load demand from the grid. Thus, this approach in fact worsens the situation and further reduces energy availability in the country.
- Initial investment costs of solar PV systems are higher compared to the initial investment costs for a grid or genset powered inverter-battery back-up systems.
- However, the cost of the **energy supplied** with a solar PV system is clearly lower compared to grid or genset powered inverter-battery back-up systems.
- In particular, despite of the high initial investment, the cost of the energy produced with a grid-connected solar PV plant is competitive even when only 50% of the investment is paid cash and 50% is financed through a loan with 9% mortgage rate.

6.3 Institutional feasibility

The analysis of the institutional set-up of the energy sector in Nepal as well as the various consultations that were conducted on the question of the feasibility of grid-connected technology during this project result in the following salient issues concerning institutional questions.

The necessity of increasing the electricity production capacity in the country is generally recognized within the institutions, and the idea of implementing grid-connected technology is in principle welcomed and even supported by most of the stakeholders. However, several institutional obstacles have been identified and would need to be overcome in order to make this happen:

- The present legal basis does not allow the connection of solar PV systems to the grid and would need to be adapted. However there is legal basis for the connection to the grid of private operated power plants based on hydro, wind and biomass, and thus there is no reason why solar PV grid connection could not be integrated in that legal framework.
- The current standards and norms do not cover the specific components of grid-connected solar PV systems, in particular for grid-connected inverters, and would need to be adapted.
- The fact that solar PV grid-connected systems are still mostly unknown among most of the institutions and politicians in Nepal makes it difficult for policy and decision makers to have confidence in this technology's ability to potentially contribute to the improvement of the availability of electricity. This is particularly true regarding the issues of technical feasibility and the cost of the technology. Decision makers need more evidence in order to be convinced that the technology is appropriate in the Nepalese context.

Regarding this last issue, the discussion is closely linked to the question of national strategic development of the overall electricity production scheme. The GoN plans are oriented towards the construction of new hydro power plants as the main production source for domestic energy. The problem is that medium to large scale hydro power plants take a relatively long time to be implemented (estimated 10 years in a politically stable context, which is currently not the case). The construction of thermal (diesel and coal fuelled) power plants could theoretically be realized in less time in order to compensate for the missing production capacity, but they have the enormous inconvenience of being totally dependent on foreign countries for their fuel supply, something that can become very unsure, as recent experience has demonstrated. Moreover, such thermal plants are characterized by low efficiency performances, high environmental impacts and expensive energy production costs (about 31 NPR/kWh in 2006), which will probably be subjected to high inflation in the coming years.
A major diversification of electricity production sources is thus advisable, and can be progressively realized through the development of renewable technologies such as wind, biomass, solar and of course small and medium scale hydro-power plants. In this perspective, the use of solar PV grid-connected systems could play an important role, and the responsible institutions should consider it as one of the components of the future energy mix, and thus to be included in the development of the energy policies of the country.

6.4 Conclusions and recommendations

The feasibility study has demonstrated that there is a very encouraging potential for solar PV grid-connected systems to be considered for Nepal. In fact, the analysis demonstrates that most of the identified obstacles can be overcome, and that this technology could effectively participate in the improvement of the country's present crisis in the energy sector. The study shows that solar PV grid-connected systems can be an important part of the country's long-term solution to address the present electricity shortage and high daily load shedding hours, as well as help meeting the fast growing electricity demand in reasonable short time periods. In addition, the stakeholder analysis has shown that the necessity of increasing the electricity production capacity in the country is generally recognized within the institutions, and the idea of implementing grid-connected solar PV systems/plants is in general welcomed and even supported by most of the decision makers.

It has been demonstrated that solar PV grid-connected systems would benefit from the excellent climatic conditions in Nepal, something which would provide additional value to the solar energy technology, both in terms of production capacity as well as cost effectiveness. In fact, compared with Southern Germany, the solar energy received on a module's surface is 74% higher in Kathmandu. Besides, the contribution of solar PV grid-connected systems to partly resolve the problem of load shedding (lack of electricity production capacity) has been demonstrated by the fact that it would allow to reduce the load, thanks not only to the reduction of consumption by the users, but also thanks to the additional injection of energy into the grid. Moreover, compared to other alternatives for increasing the electricity production capacity in the country, solar PV grid-connected systems presents the following advantages:

- they are very efficient, in terms of productivity (kWh/kW installed capacity) in Nepal's good and favourable climatic conditions (high annual solar insulation);
- they can be rapidly implemented (in a matter of weeks or months rather than the years needed to implant hydro power plants);
- with their “fuel” being a renewable energy resource, solar PV systems are independent from the need of an external, often fossil, energy source (like diesel or coal). This not only means the “fuel” of a solar PV system is easily available to anyone free of cost, but it is also positive for the important issues of the country's energy security, unpredictable fuel cost curve and inter-political tension;
- they provide interesting professional and local economy opportunities in terms of employment, education and new business ventures;
- they have a very small carbon footprint and once installed and running are environmentally very clean;
- with regards to effects on the grid, they are very appropriate, and in fact very supportive to the grid compared to present alternatives used for dealing with the load shedding periods (genset, inverters + batteries). Solar PV grid-connected systems support the grid in various ways rather than weakening it;
- they are becoming more and more economically competitive compared to present alternatives used to deal with the load shedding periods.

However, there are still various obstacles that need to be addressed before the technology becomes fully implementable, as follows:

Technical obstacles

- Grid instability and characteristics. Every year they are a lot of total system collapses caused by disturbances such as the breakdown of large generators or contingencies on heavy loaded lines. The grid voltage can reach values near the authorized limits, in particular the average voltage measured *in-situ* show voltage values near or even below the minimal authorized value. Besides, excessive Total Harmonic Distortions (THD) have also been observed;
- Presently, very frequent load shedding schemes would not allow a grid-connected PV system to function ideally. Pilot demonstration plants should be constructed first in places with full access to the grid;
- Grid-connected inverters are not yet available in Nepal. The setup parameters of currently available inverters would need to be adapted to the parameters of the Nepalese grid. The adaptation of such parameters can be easily realized by the manufacturers and importers of inverters;

- There is no specific professional training or course on grid-connected solar PV systems. It is necessary to promote practical knowledge on solar PV energy grid-connected, feed-in systems. Promotion should also take place in universities, so as to train competent planners and installers for the future.

Economic obstacles

- Though the cost of energy produced with grid-connected solar PV systems is competitive (compared with other alternatives to the grid power), the **high initial investment** is a serious obstacle.

Some specific markets (for inverters and partially for appropriate solar PV modules) do not exist yet and thus would need to be developed.**Institutional obstacles**

- The actual legal basis does not allow the connection of PV systems to the grid, thus new legislation would need to be introduced;
- The current standards and norms do not yet cover the specific components of grid-connected solar PV technologies. In particular the standards for suitable grid-connected inverters need to be developed and introduced;
- Politicians, policy and decision makers need to be more aware of the solar PV grid-connected technology's potential and advantages for Nepal. They need clear evidence of its appropriateness in the Nepalese context in order to support its development.

Recommendations

As discussed above, several barriers still hinder a full development and installation of solar PV grid-connected systems in Nepal. The following list of recommendations aims to provide possible ways to remove them, or at least reduce their importance.

Legalisation on the technology
The solar PV grid-connected technology should be made legally possible. As discussed in chapter 6.1, specific technical conditions need to be respected and established.

Adaptation of standards and norms
The current standards and norms need to be modified in order to also include the equipment used for solar PV grid-connected systems, in particular the inverters. This aspect is important for the quality of the systems and for the establishment of a fair market.
In particular, it is recommended:

- to accept IEC certifications realized by ISO recognized agencies without requirement of additional tests;
- **not** to require confidential ISO17025 test reports of the IEC 61215 norm from the solar PV module suppliers, which would be disclosing their technological knowhow and manufacturing process, i.e. revealing corporate secrets to competitors.

Communication campaign and demonstration
The characteristics (advantages, limits, opportunities and risks) of solar PV grid-connected systems in the context of Nepal should be made known more widely among the institutions, the governing bodies, the local industry and the public.
The construction of one to three pilot solar PV grid-connected demonstration plants in Nepal would be an excellent way to convince decision makers and possible users through actual, real-scale systems that the technology works. Also, these prototype systems could function as real-life examples for the economic evaluation of the technology. Some pilot plants should be constructed in places that have full access to power (without load shedding) such as hospitals, government offices, and NEA buildings, while other pilot plants should be built with additional energy storage facilities, so that they can be installed, tested and act as demonstration plants within the local communities All pilot systems should be closely monitored, and their performance should be recorded with specially designed data monitoring and recording systems.

Education

Teaching of grid-connected technology development, construction and maintenance should be integrated into training programmes at various levels (professional installers, dealers and engineers).

Market stimulation

The development of the technology in Nepal should be supported by various measures aiming to facilitate and stimulate the market. Some possibilities which need to be considered are as follows:

- provide VAT reduction also to inverters for grid-connected solar PV plants (for example the VAT reduction that is currently provided for PV modules, 2.5 % instead of 13%);
- develop specific incentives schemes for grid-connected PV plants. Various options are possible, and international best practices should be analysed in order to define an appropriate scheme for Nepal. For example, to start with, a scheme that would pay back the energy fed into the grid by the PV plant at the same rate as the energy bought from the grid. If specific budget can be allowed for the promotion of the technology, a higher acquisition cost could be practiced, as it is the case in various European countries;
- Create more favourable bank rates for financial loans for grid-connected solar PV plants (as proposed above through CEDB, offering 9%, but this value could be even lower if the government agreed to support the activity and introduced the right legislative tools);
- Thin film solar PV modules are complex, and the measurement of their characteristics requires specific equipment and knowhow that are not yet available in Nepal. RETS laboratory should receive support in this domain in order to allow this technology to be adopted in Nepal. If the testing of thin film modules is not made possible, these would be penalized because they could not benefit from VAT reduction.

This list of recommendations is by no means exhaustive, and other measures could be implemented according to the stakeholders' interests and capacities. It is a matter of fact that the introduction of a new technology, such as grid-connected solar PV systems, often faces initial resistance from key stakeholders and individuals. This happens partly because of the lack of knowledge and familiarity with the new technology. In the case of grid-connected solar PV systems, the fact that it has been implemented with great success and since many years in various countries must be considered, and thus will play an important role in the raising of awareness.

The obstacles that are still hindering the applicability of grid-connected technology in the Nepalese context, as analyzed in the present report, have to be addressed in order to take advantage of this sustainable energy source in a near future in Nepal.

In this perspective, the realization of PV grid-connected pilot plants would certainly be of great value in demonstrating and monitoring the qualities and risks of such application in the particular context of Nepal. In any case, it represents a necessary step towards larger scale dissemination, as it has successfully been demonstrated in many other nations.

7 Training programme

In parallel to this feasibility study, a training programme was organized and delivered in collaboration with the three partners involved in this project. It included the following three main components:

1. Initial seminar on development of PV grid-connected plants in Nepal, hold on April 6th and 7th, 2009 at CES/TU in Kathmandu.
2. Involvement of students in the implementation of the feasibility study.
3. Closure seminar on the result of the feasibility study, hold...

Thirty-one students, seven academics from KU, TU and SUPSI, and members of the public and private sector attended the first seminar This two days course allowed to build a common understanding of the Nepalese energy sector characteristics and on solar PV technology in general as well as PV grid-connected technology in particular. The programme and content of lectures are listed below, the corresponding presentations can be requested at: WorldHabitat@supsi.ch.

1: National strategy, NEA policies, general context

- *National strategy for electricity production*
- *NEA policy*
- *Legal context of grid IPPs*
- *Legal basis for grid fed technologies*
- *Incentives scheme for RE*
- *Population and economic activities scheme*
- *Social acceptability*

2: Basics on RE, resources, PV

- *World Energy scenario*
- *World RE resources*
- *Solar resources (including meteo data)*
- *Solar PV basics/process*
- *PV pro/cons*

3: NEA Power/Energy generation & use

- *NEA Statistics of MW built*
- *Power generation, transmission and distribution schemes*
- *Economical mechanisms, costs*
- *GWh generated over time*
- *Power/Energy uses (market)*
- *Growth pattern*
- *Growth distribution*
- *Load shedding history*
- *Power import/export*
- *Standards and norms*

4: PV Systems, social aspects, local availability

- *BoS*
- *Energy storage*
- *PV life cycle (CO2 emissions)*
- *PV Power production*
- *Operation and maintenance (O & M)*
- *Local availability of technology, material, know-how*
- *Users characteristics (power, phases, voltage, costs)*
- *Practical examples*

5: The International situation

- *PV Trends*
- *Incentives schemes, policies and economics for PV Grid connection in various countries*

6: PV Systems, social aspects, local availability

- *PV Systems (RAPS)*
- *Designing PV Systems*

7-12: Grid-connected systems

- *Grid-connected PV system (inverter, BOS, etc.)*
- *Available PV grid connection technologies (including materials, inverters)*
- *Dimensioning grid-connected PV plant*
- *Examples of PV grid connection*
- *System losses in PV grid-connected technology*
- *Experiences, failures, trends and standards*
- *Lighting protections and DC Danger*
- *Mini grids*
- *Simple simulation tools*
- *PVSYST and other*

Secondly, the involvement of students from both KU and TU consisted mainly in carrying out the surveys with both the industry/service sector and the domestic users. The questionnaires were first designed and tested by the project team representatives, and KU students then carried out the survey with domestic users, while TU students were charged with the survey with the industry/service sector.

The second seminar took place on November 9th, 2009 at CES/TU campus in Kathmandu. The programme was the following:

- Technical barriers for PV grid-connected system
- Dimensioning of PVGC
- Grid conditions
- Cost, barriers, social impact
- Simulation (with PVSyst)
- Survey results and feasibility study

Fig. 7.1: picture of the participants in the first seminar in April 2009. In the background, the BIPV plant of CES/IOE, Tribhuvan University, Lalitpur.

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Annexes

1. Questionnaire to Industry sector potential users
2. Questionnaire to domestic/private sector potential users

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The industry point of view

A questionnaire addressed to a selected group of production and service industries

Industry type (tick):

☐ Small scale production facility ☐ Small hotel/lodge

☐ Internet service providers ☐ Software developers

☐ Airlines ticketing, travel agencies ☐ Cyber café

☐ Others (medium or large production facility, hotel or other –please precise-) ………………………

1 How does your company manage power supply during load shedding periods? And how much does it cost?

	COSTS:
☐ deal with the inconvenience and wait for better times	
☐ use a Petrol run generator	…… Rs/year …… Liters/year
☐ use a Diesel run generator	…… Rs/year …… Liters/year
☐ use a LPG (gas) run generator	…… Rs/year …… Cylinder/year
☐ use a inverter-battery system	…… Rs/year
☐ use a solar PV-battery system	…… Rs/year
☐ Other………………………………………	…… Rs/year

2 Knowing that:

- The actual cost of your electricity is 7.30 Rs/KWh
- Your average monthly consumption is about………..KWh, costing about ………………Rs/month (please complete)
- The cost of electricity for a small company with a generator is approximately
  - o Diesel generator: about 30 Rs per KWh
  - o Petrol generator: about 40 Rs per KWh
  - o LPG generator: about 40 Rs per KWh

How much is your company ready to pay for a reliable power supply for 24 hours / 7 days?

☐ 40 Rs/KWh ☐ 50 Rs/KWh ☐ 60 Rs/KWh

3. Is your industry/business space rented or you own it?

☐ rented ☐ own it

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4. Do you have authority to use the space available on the roof and the ground of the building? (*for rented office space only*)

☐ yes ☐ No

(even if the answer is no, please respond to questions 5 to 8 for providing information)

5 What use are you making of your roof or available free space on the ground? (*for industries with owned building/spaces*) ?
(more than one answer are possible here)

☐ nothing on the roof ☐ ground space for parking and other uses

☐ … … … … … … ☐ ……………………………..

6 How big is the free surface area available in the roof or ground?

☐ 20 sqm ☐ 30 sqm ☐ 40 sqm ☐ 50 sqm ☐ 100 sqm

☐ … … … … … … … .

7 If you would receive a compensation for the use of space, how many square meters of space would you agree to lease for PV modules installation?

☐ 5 sqm ☐ 10 sqm ☐ 20 sqm ☐ 50 sqm ☐ 100 sqm

☐ … … … … … … … … … …

8 If you would have a "cluster" of solar PV system installed on your premises (which produces power not only to your consumption but to a group of neighborhood's), would you prefer to give access to the space to external staff for regular cleaning of the modules or would you prefer doing this work with your own means/staff?

☐ I prefer external staff for cleaning ☐ I prefer to arrange the cleaning myself

9 What importance does your company give to the issue of sustainable and clean energy for the future of Nepal?

☐ It does not care, it is not important at all for the company

☐ It may be important but anyway we can not do anything to change the way it is

☐ We think it is important, we would like to do something to improve the situation but we does not know what and how

☐ We are convinced that it is important and the company does something to improve the situation (try to save energy, look for alternative energy solutions, discuss the matter with my friends and colleagues, search information in order to know better what are the possibilities for energy savings, instruct the employees on energy saving measures at work).

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Development of PV grid connected plants in Nepal.
A feasibility study and training programme

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The users point of view

A questionnaire addressed to a selected group of upper middle class urban families

1 How do you manage power supply during load shedding periods?

- ☐ I just deal with the inconvenience and wait for better times
- ☐ I use a Petrol run generator
- ☐ I use a Diesel run generator
- ☐ I use a LPG (gas) run generator
- ☐ I use a inverter-battery system
- ☐ I use a solar PV-battery system

3 How much are you ready to pay for a reliable power supply 24 hours / 7 days? Knowing that:

- The actual cost of your electricity is 7,30 Rs/KWh
- Your average monthly consumption is about 300 KWh, costing about 2'200 Rs/month
- The cost of electricity for a home system with a generator is
  - Diesel generator: about 50 Rs per KWh (costs to check)
  - Petrol generator: about 60 Rs per KWh
  - LPG generator: about xx Rs per KWh

☐ 10 Rs/KWh	☐ 20 Rs/KWh	☐ 30 Rs/KWh	☐ 40 Rs/KWh	☐ 50 Rs/KWh
(3'000 Rs/month)	(6'000 Rs/month)	(9'000 Rs/month)	(12'000 Rs/month)	(15'000 Rs/month)

Monthly costs per 300 KWh/month (value to check)

3 Select the electric appliances you have at home among the followings:

... ☐ Lighting ... ☐ Fridge ... ☐ Computer

... ☐ TV ... ☐ Radio/HIFI ... ☐ AC

... ☐ Washing machine ... ☐ Oven ... ☐ Iron

... ☐ Grinder ... ☐ Micro-wave oven ... ☐ Electric heater

... ☐ Electric boiler (for bath) ... ☐ Electric boiler (for kitchen) ... ☐ Fan

... ☐ water pump ... ☐ Rice cooker

4 Give a priority of importance you consider for the appliances listed on question 3 (number 1= the most important, and so on).

Please write the order of importance in front of each box.

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7 What use are you making of your roof?
(more than one answer are possible here)

☐ cloth washing ☐ other works outside

☐ social gathering (parties) ☐ outdoor space for enjoying the sun

8 How big is the surface of you roof?

☐ 20 sqm ☐ 30 sqm ☐ 40 sqm ☐ 50 sqm ☐ 100 sqm

7 If you would receive a compensation for the use of space, how many square meters of roof space would you agree to leave for PV modules installation?

☐ 5 sqm ☐ 10 sqm ☐ 20 sqm ☐ 50 sqm ☐ 100 sqm

8 If you would have a “cluster” solar PV system installed on your roof (which produces power not only to your house but to a group of neighborhood’s houses), would you prefer to give access to the roof to external staff for regular cleaning of the modules or would you prefer doing this work with your own means/staff?

☐ I prefer external staff for cleaning ☐ I prefer to arrange the cleaning myself

9 In what ways does the load shedding periods affect your daily life?

☐ Loss of work capacity and diminution of income
☐ Difficulties in food storage (fridge not operating regularly
☐ Disturbance of social activities
☐ Disturbance of education ad study activities
☐ Disturbance for water supply (pumping)
☐ Health hazards (depression)

10 What importance do you give to the issue of sustainable and clean energy for the future of Nepal?

☐ I do not care, it is not important at all for me
☐ It may be important but anyway I cannot do anything to change the way it is

☐ I think it is important, I would like to do something to improve the situation but I do not know what and how

☐ I am convinced that it is important and I personally do something to improve the situation (I try to save energy, I look for alternative energy solutions, I discuss the matter with my friends and colleagues and search information in order to know better what are the possibilities for energy savings, I teach my children to save energy and explain them why,…).