Volume III - 2016

ENERGY INSIGHT

A Yearly Publication of **PEEDA**

PEEDA

Editors: Biraj Gautam & Tapendra Chand

FROM THE CHAIRPERSON

Murali Prasad Sharma
Chairperson, PEEDA

The role of non-government organizations is indispensible for a country like Nepal and is considered as one of the major actors in the socio-economic development. The northern countries and international agencies consider NGOs as alternate institutional mechanisms for the transfer of resources to the needy community and also for understanding the reality of the developing countries. Initiatives taken by NGOs in all sectors including that in energy and environment have significantly contributed to the upliftment in living standard of rural people through just and right-based approach in promotion of energy systems.

People, Energy & Environment Development Association (PEEDA) is an NGO dedicated to improve livelihoods of communities, particularly the poor, by collective utilization of renewable energy (RE) resources, while ensuring due care for the environment. It mainly focuses on institutional development, promotion of cooperation to undertake projects, advocacy and targeted research. We believe that poverty will substantially be reduced through effective, socially responsible and environmentally sustainable RE development.

Since its establishment, PEEDA has been undertaking innovative initiatives esp. pertaining to hydropower development through initiation of PPHP concept and promotion of two institutions e.g. -Hydro Lab P. Ltd. established for hydraulic modeling and Hydro Consult Engg. Ltd. established for providing quality engineering consultancy services. PEEDA is also undertaking developmental projects and carrying out research activities.

I am greatly delighted that PEEDA has been able to publish a publication that serves both promotion and knowledge sharing among wider stakeholders. I hope that this publication would assist in increasing awareness on the sector. I would like to acknowledge the efforts of PEEDA management team in bringing out this annual publication. Lastly, I would also like to extend my sincere thanks and gratitude to the Executive Committee, members, development partners and all other stakeholders for their invaluable contributions to PEEDA.

Thank you!!!

FROM THE CHIEF EXECUTIVE OFFICER

Biraj Gautam
Chief Executive Officer, PEEDA

Nepal's energy system needs to be adapted into a more sustainable one, based on a diverse mix of energy sources, addressing the pressing challenges of security of supply and climate change. In accordance with the fact that there is sharp increase in oil and natural gas prices, renewable source of energy can be used as a substitute for fossil fuels and may reduce the dependence on imports and/or the greenhouse gas emissions. Nevertheless, different forms of renewable energy other than hydro-power are not yet commercially successful in Nepal because of various limitations and discrepancies.

PEEDA has been conducting various energy and environment related activities and projects over the last 19 years. PEEDA has been exploring and executing concepts and technologies that could impact lives both on shorter and longer terms. PEEDA is currently executing four projects and has been playing a significant role in the development of sustainable energy in Nepal.

After conducting numerous activities and research, PEEDA has taken this opportunity to disseminate information. It is also imperative to bring together other works on Renewable Energy and Environment so that a collaborative effort could be instigated for sustainable development. Hence, this yearly publication called "Energy Insight" has articles and research papers on various technologies as well as concept notes on different relevant projects.

After successful publication of "Energy Insight" last year, this is the third attempt to deliver the findings to the concerned stakeholders. However, I do acknowledge that there might be plenty of shortcomings both with regards to the content or the concept as such. I sincerely do hope that your valuable comments, suggestions and timely advices would help us to put together a better publication in the years ahead.

I greatly appreciate the individual authors who voluntarily contributed by sharing their views and findings in this publication. Finally, I would also like to sincerely thank the Chairperson, the Executive Committee, my colleagues, partners specifically WISIONS and the publishers for their support in bringing out this publication. Last but not the least; I would like to thank WISIONS for their financial contribution for the publication of this magazine.

Thank you!!!

TABLE OF CONTENT

FIXED DOME DESIGN BIOGAS CONSTRUCTION PROCESS

Govinda Prasad Devkota
Freelance Consultant
Kathmandu, Nepal
E-mail: govindadevkota@yahoo.com

INTRODUCTION:

The success of a biogas plant depends upon the quality of construction as well as quality of construction materials used. Here is presented a simple construction process of the fixed dome design biogas plant developed by Gobar Gas Company in Nepal. The following Fig 1 is the cross sectional view of a fixed dome design biogas plants with its dimensions in centimeters. Here are presented the measurements of the fixed dome design biogas plants of the size ranging from 4 to 20 cum capacity.

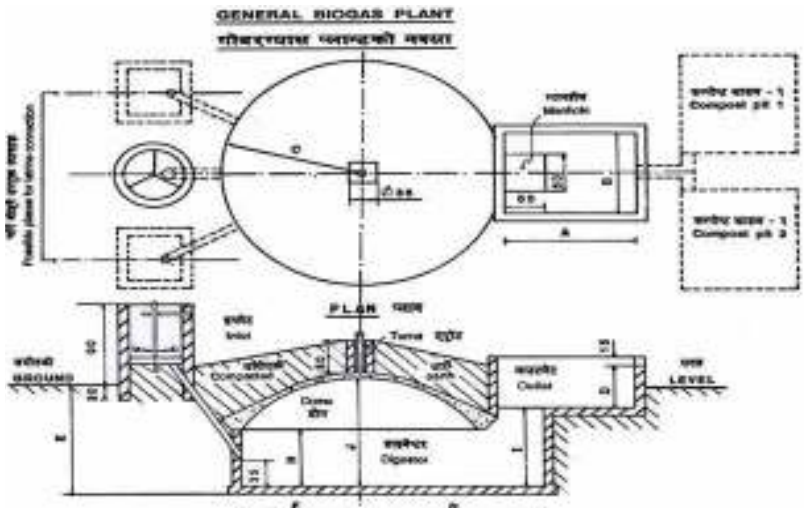


Fig. 1: Cross sectional view of the fixed dome design biogas plant (GGC Model 2047)

MEASUREMENT OF DIFFERENT SIZE OF BIOGAS PLANTS:

As shown in the diagram, the measurements for different size of the plants of different parts are as shown in the table 1.

Table 1: Measurements of different parts of the plants

Part of the plant	Plants size in Cubic meter					
	4	6	8	10	15	20
A	140	150	174	180	248	264
B	120	120	130	125	125	176
C	135	151	170	183	205	233
D	50	60	65	68	84	86
E	154	155	172	168	180	203
F	102	122	135	154	175	199
G	185	211	221	240	261	288
H	86	92	105	94	115	115
I	112	116	127	124	132	137
J	151	110	175	171	193	203

Note: All the measurements are given in Centimeter.

While installing a plant one should bear in mind that;

1) All the measurement is given in centimeter.
2) Inlet, outlet and turret should be in straight line.
3) Toilet pipe should be placed as close as possible with the inlet pipe.
4) The floor of the digester should be in stable and compact ground.
5) The cement sand ratio for making wall should be 1:4.
6) The inside digester wall should be plastered with 1:3 cement sand mortar.
7) Stone wall should be as close as the pit wall.
8) The entire brick wall should be compacted with mud externally.
9) While making mud dome appropriate size of the template should be used.
10) For concreting dome, the ratio should be 1:3:3. Should not use concrete older than two hours.
11 Dome should be protected from sun and needs about 6 days for setting.
12) The plastering of the dome is very important.
13) The gobar gas is not completed unless, there is no top filling, no slab on outlet and no compost pit.

CONSTRUCTION MATERIALS NEED FOR DIFFERENT SIZE OF THE PLANT

The following table no. 2 shows the quantity of the construction materials needed for different sizes of the plants. The quality of the bricks should be number one and well burnt with good shape and size. If stones are used they should be mud free and of good size and shape. Likewise, sand should be mud and vegetables free otherwise need to wash it before using. Peebles should be of appropriate size and cement should be fresh and without any lumps. The water used to mix concrete should be like that of drinking water and without any mud.

1. Cement:
   - High quality portland cement
   - Should not be used if moist or with lumps.

2. Sand:
   - Should not use poor quality sand.
   - If it has more than 3% impurities, it should be washed with clean water and use.
   - Coarse sand is better for casting and fine sand for plastering.

3. Water:
   - Should not use dirty water.
   - Better to use drinkable water.

4. Aggregate:
   - Should be of the right size (0.5 – 2.5 cm).
   - Should be cleaned.

5. Bricks/sand:
   - First class brick.
   - With proper shape.
   - Stone should not be too soft.

Table 2: Quantity of construction materials needed

No	Particulars	Plant size in cubic meter					
		4	6	8	10	15	20
1	Bricks/Stone (Pc)	1200	1400	1700	2000	2400	2800
2	Sand (bag)	60	70	80	90	110	120
3	Pebbles (bag)	30	35	40	50	60	70
4	Rod 8mm (kg)	10.5	10.5	13.5	13.5	18	44
5	Cement (bag)						
	• Terai (bricks)	11	13	16	19	27	34
	• Hills (stone)	12	14	18	21	30	37

SITE SELECTION

While selecting biogas construction site one should bear in mind that it should be;

a) Sunny place
b) Water source within 20 minutes.
c) Kitchen as close as possible.
d) About 10m away from the well.
e) Adequate space for making compost pit.

LAYOUT

Before installing a plant, one should make a proper layout of the plant which will locate the places of inlet, outlet, digester and the compost pits. It can be marked with lime or ash and can start digging.

a. Fix the place for inlet, digester, outlet and compost pit.
b. Use lime or ash for making layout.
c. Dig pit as per the measurement and layout.

SOLING

Soling of the digester floor should be in the stable and compact floor. Pour concrete on top of stone or brick layer placed properly.

ROUND WALL

a. Place ½ inch GI pipe vertically at the centre.
b. Place another pipe horizontally and tie them up.
c. Now start making round wall, taking measurement from the centre.

DIGESTER CONSTRUCTION

a. Once the pit is completed the level of the digester floor should be in hard or natural soil.
b. Take the radius with 1 cm more for plastering.
c. The first layer of the round wall should be from the width where as others from the length of the brick.
d. There should be proper back filling by adding little water and gentle tapping.
e. Stone wall should be as close as the mud wall.
f. The concrete ratio should be from 1:4 to 1:6 depending on the quality of the sand.
g. The inlet pipe should be placed 35cm above from the floor of the digester.
h. After completing the brick wall, it should be plastered with 1:3 cement sand mortar and should be 10 mm thick.

DOME CONSTRUCTION

a. There should be proper back filling before making mud dome.
b. Measure the height from the bottom of the digester to the top of the dome, mark them and fill mud up to that level.

DOME CONSTRUCTION

a. There should be proper back filling before making mud dome.
b. Measure the height from the bottom of the digester to the top of the dome, mark them and fill mud up to that level.
c. Now replace ½ inch GI pipe 50 cm buried in the mud dome.
d. Use template for making proper shape of the dome.
e. Put thin layer of sand on top of the dome.
f. ½ inch GI pipe to be replaced with main gas pipe.
g. The dome should be casted with 1:3:3 concrete.
h. The thickness of the dome should be 6 – 8 cm at the centre and 25 cm at the edges.
i. Protect it from the sun and pour water 4-5 times a day for about a week.
j. Make turret on the second day of casting dome.
k. Remove mud from the digester after about a week.

INLET CONSTRUCTION

a) Place mixing machine in the inlet tank.
b) The surface of the floor of inlet should be 5 cm above from the overflow of the slurry level.
c) The height of the inlet pit should be 50 – 100 cm.
d) If mixing machine is placed, the blade of the machine to the wall should be not more than 2 cm gap.

OUTLET CONSTRUCTION

a. The floor of the outlet should be stable.
b. The size of the outlet should be as given in the drawing.
c. It should be plastered with 1:3 cement sand mortar.
d. The wall should be properly back filling.
e. It should be slightly above the ground.
f. The cover of the outlet can be made at the time of casting dome. These slabs should also be cured properly.
g. The thickness of the slab should be 3 inch and should be casted on plain floor or on top of plastic sheets.

GAS PIPE, MAIN GAS VALVE AND TURRET CONSTRUCTION

a. ½ inch pipe placed at the centre of the dome should be replaced with main gas pipe while casting dome.
b. Turret should be constructed next day on the top of the dome and should be 50 cm high and 36 cm radius.
c. Main gas valve should be placed right after the main gas pipe.
d. There should not be any unnecessary fittings between main gas pipe and gas valve.
e. Main gas valve should be closed when gas is not being used.

PROCESS OF PLASTERING DOME

a. It should be cleaned with water and wire brush, once we remove mud from the dome.
b. Apply a layer of cement water solution.
c. Plaster 10 mm thick with 1:2 cement sand mortar.
d. Plaster 5 mm thick with 1:1 cement sand mortar on the next day.
e. Mix 1.5 portion of paint with 20 portion of cement and apply inside the dome.
f. Mix 1 portion of acrylic plastic emulsion paint with 2 portion of cement and apply inside the dome with the help of brush.

WATER DRAIN PIT CONSTRUCTION

a. It should be placed at the lowest level of the pipe line.
b. The wall of the drain pit should be 40 cm x 40 cm (inside) and 50 cm depth.
c. The wall should be about 5 cm above the ground level.
d. The water drain should be placed 30 cm below the ground level.
e. The cover of the pit should be 66 cm x 66 cm.

PIPE LINE CONSTRUCTION

a. All the pipe fittings should be done using taflon tape.
b. Avoid unnecessary fitting and union.
c. The pipe line should be 1 feet below the ground level.

COMPOST PIT

a. There should be 2 compost pits, about 1 m far from the outlet chamber.
b. It should not be more than 1 m depth and the distance of two pits should be minimum of 50 cm.

TOP FILLING OF THE DOME

In order to protect the dome from cold and get more gas, the dome should be covered with mud (40 cm high).

DAILY FEEDING

The initial dung required and the daily feeding with cattle numbers for different sizes of the plants installed in hills or terai are as shown in the table 3.

Table 3: Initial dung required and daily feeding

No	Size (Cu.m)	Initial dung (kg)	Daily feeding (kg)		Daily water (litre)		No of cattle
			Hills	Terai	Hills	Terai	
1	4	1450	24	30	24	30	2-3
2	6	2200	36	45	36	45	3-4
3	8	2900	48	60	48	60	4-6
4	10	3500	60	75	60	75	6-9
5	15	5500	90	110	90	110	9-14
6	20	7200	120	150	120	150	14 and above

QUALITY BIOGAS PLANT

Quality of the biogas is considered good if;

1. The plant is daily fed with the right quality of dung and water.
2. It is constructed as per the drawing given.
3. There is no any leakage through pipe line.
4. There is adequate top filling on the dome.
5. There is pipe line 1 foot below the ground level.
6. There is adequate gas production and the user is satisfied with the plant.

MODULAR RENEWABLE MICROGRIDS FOR RURAL ELECTRIFICATION

Sam Williamson* & Biraj Gautam**
*University of Bristol, E-mail: sam.williamson@bristol.ac.uk
**Chief Executive Officer, PEEDA, E-mail: biraj@peeda.net

Microgrids are defined by CIGRE (International Council on Large Electric Systems) as "electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while islanded."

Imagine a remote community in the middle hills of Nepal. There's a local pico hydro system running supplying 10 homes, several households have got solar home systems, and the local school has a PV array on its roof. Individually, none of these supplies is able to support any income generating equipment, a flour mill, rice husker or saw mill. When one of the units fails, the homes or school lose their electricity supply. If the community saves up to install another pico hydro system for an additional 10 homes, then there is no real way to connect the two units together. So, what is the solution to this?

Connecting together the sources and loads to form an islanded microgrid allows a robust, more reliable and more resilient electrical system, that is able to support larger loads and can be expanded as more units are bought. It also allows larger loads, such as mills, to be connected to the system, so the community can use the power to generate an income which makes the system more financially sustainable.

Together with PEEDA, the University of Bristol first started working on this through the concept of a pico hydro off-grid network, where a number of identical pico hydro turbines are connected together to for a microgrid, as shown in Figure 1.

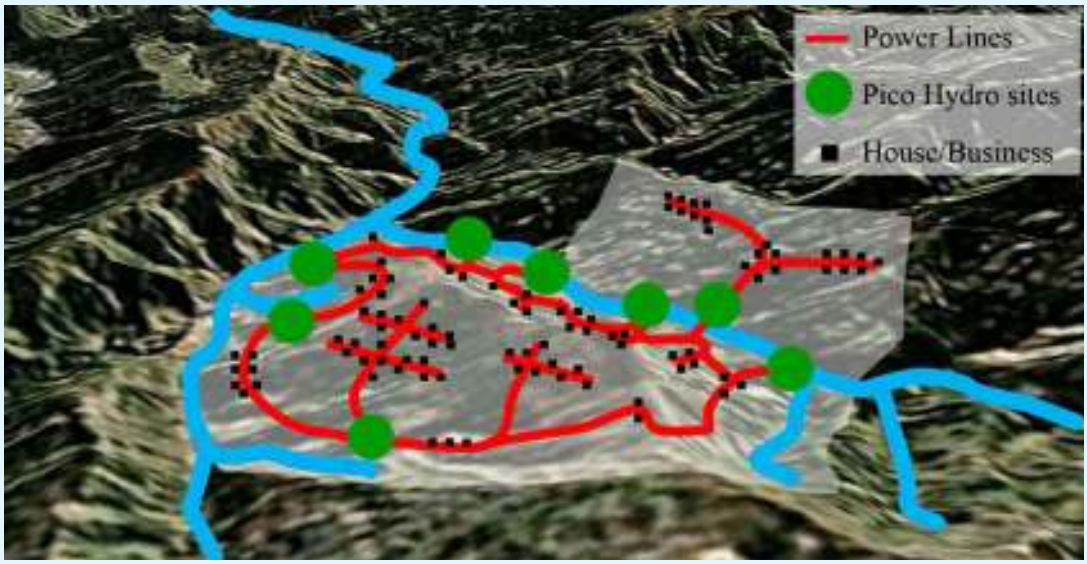


Figure 1: The pico hydropower off-grid network concept, where identical pico hydro units are connected together to form a reliant, resilient network able to support commercial activities.

This concept can be expanded to consider other renewable energy sources such as solar photovoltaics, wind turbines or biomass systems. If the grid becomes available, this can be connected to the grid and the microgrid can become an importer/exporter to the grid, with a potential for an additional income stream. As capital becomes available other renewable sources can be purchased and plugged into the grid with no changes to other sources or loads on the grid.

To achieve this, each source needs to be interfaced onto the grid using a power electronic converter. The aim of the current research project is to develop 3 interfaces for the grid: a source converter for renewable resources, a storage converter for batteries or other storage elements, and a load converter for the consumer. If the power generated or consumed is larger than the rated power of the converters then the converters can be connected in parallel. This idea is shown in Figure 2.

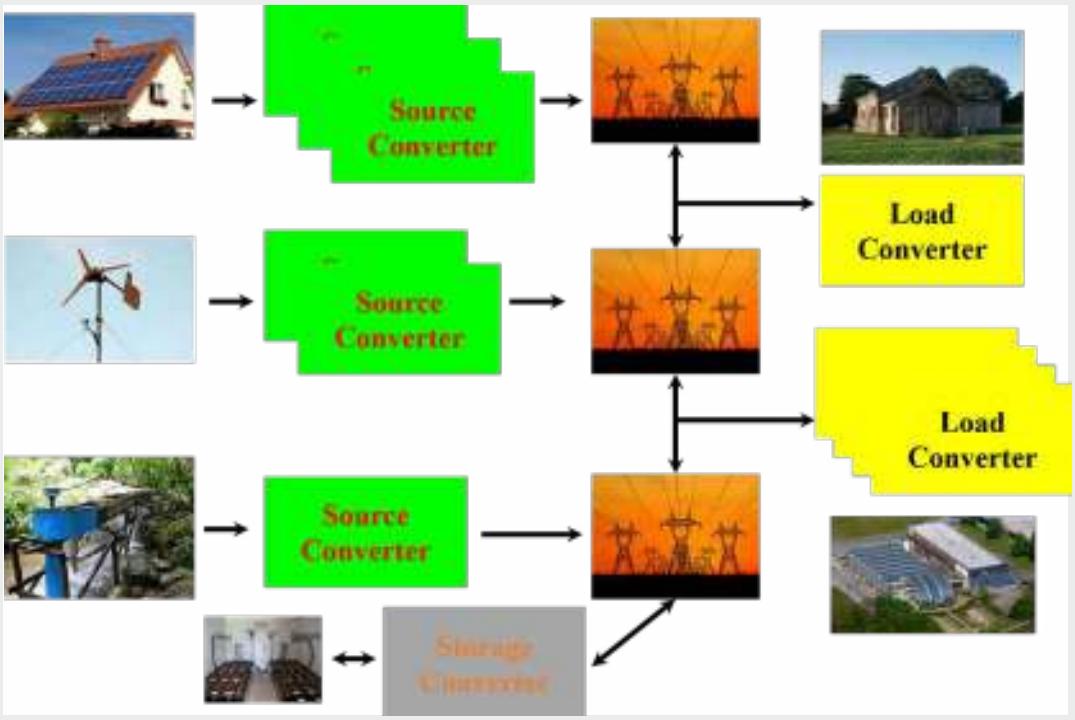


Figure 2: Modular interfaces for the renewable microgrid.

Let's return to our village in the Nepali middle hills. What would this system be able to do for them? Well, their pico hydro, solar home systems and school's PV array could all be connected together, giving them a larger total supply that is more reliable, resilient and flexible. If they decide to develop a second pico or micro hydro system, then this could be added to the system and feed into it. The power from the system can be used to drive a mill to process the local crops, adding value to the produce and allowing the farmers to get more money. A local saw mill can be set up to use the power during the day when people are working, using the local wood to make products for the community and selling to the open market. The local school could generate an income from their PV array, and are able to buy more materials for the children and set up a communications link where they can talk to people all over the world.

This project is currently in the design and modeling stage. We hope to be able to develop the technology in the lab and test in the field soon.

LOW HEAD PICO HYDRO- A ROBUST RURAL RENEWABLE ENERGY TECHNOLOGY FOR REMOTE AREAS OF NEPAL

Biraj Gautam* & Tapendra Chand**
*Chief Executive Officer, PEEDA
**Project Officer, PEEDA

BACKGROUND

Many rural areas in Nepal are still deprived of electricity and the people residing in those areas are thus compelled to use traditional form of energy sources for the fulfillment of daily energy requirement. However, because of continuous approach of various relevant stakeholders (both national and international), access to electricity in the rural areas of Nepal has remarkably improved and is continuously paving its way towards the perceived goal. Different capacities of micro-hydro and pico-hydro systems have contributed towards rural electrification. Some remote communities with suitable water resources are able to employ micro-hydro installations to produce power, but there are still large number of existing communities that neither have the pre- conditions required for a micro hydro scheme (head and flow, investments, relatively dense population) nor are likely to be electrified through the national grid due to the cost involved.

Hence, a viable and cost-effective option for such communities could be pico-hydro systems for smaller scale energy demand fulfillment. Furthermore, the development of micro-grid comprising of 2 or more than 2 pico hydro sets can fulfill commercial electricity demand of the communities for purposes liker agro-processing industries, saw mills, etc. Thus developed micro-grid can additionally assimilate other systems such as photo-voltaic solar system, wind, biomass, etc. consequently developing hybrid system that can electrify remote areas that do have very few possibilities to the access of national grid.

On the other hand, a discourse has come into play questioning the suitability/sufficiency of the power generated by pico hydro systems. We believe that the importance of this technology is even wider. We have experienced that the energy demand in any communities is very low at the initial stage. The energy demand increases with time because of desire for use of new technologies. With the advancement in the technologies such as hybrid micro grid for the decentralized generation, the use and importance of these pico-hydro units are even more as the renewable energy technologies complements to each other.

ROBUST TECHNOLOGY THAT PEEDA IS PROMOTING

PEEDA is currently implementing the project namely "Demonstration of sustainable low head pico-hydro to deliver enhanced rural energy services" in two VDCs of Okhaldhunga district namely Toksel and Katunje for installation of 3 KW and 1 KW system respectively. WISIONS (Germany), the donor of this project has supported and promoted the effective dissemination of the technology in the project areas and is willing to support in the future too. This project will provide energy access to the allocated project areas of eastern Nepal through the use of tested and robust low head pico-hydro technology.

CASE STUDY OF MOLUNG KHOLA PICO-HYDRO (3 KW SYSTEM)

The project site is located at Molung Dovan ward no 01 of Toksel VDC of Okhaldhunga district. The place can be accessed by traveling about seven hours on public vehicle from Kathmandu to Sindhuli (Naagthan) or Okhaldhunga (Harkapur) and from then onwards, another one and half hours walk. The source of Molung khola pico hydro is Molung Khola which flows along the village where the project is ongoing.

The project will benefit 16 households in total. The community comprises of Brahmins, Chhetris, Dalits and Janajatis and is mostly farmers with no access to electricity supplied from the national grid. However, few of the households are currently using solar home systems (20-50 Wp) for lighting which, however, is not reliable as far as performance and reliability is concerned. Thus, they desperately need electricity for lighting and other purposes such as for television, refrigerator (as it is very hot and humid specifically during summer), mobile charging, etc. Additionally, as of now, the community people are drinking unhygienic river water directly without any purification system. Hence, PEEDA has prioritized providing clean drinking water solution to them and is thus looking into different options. Since, clean drinking water is very essential for the villagers, PEEDA has been exploring different co-funding options to establish water purification and supply system. Furthermore, specifically during rainy season, river water consists of mud and soil and drinking such water has consequently resulted in water borne diseases among the villagers specifically children and old people. Majority of the villagers are poor and have little access to good health facilities. As such, these villagers have frequent health related problems which has been the major problem of the community villagers. In addition to this, the villagers face difficulties in fetching water spending a considerable amount of time which could be utilized for productive activities once the water supply system is installed.

The allocated project areas have existing irrigation canals that extract reasonable quantities of water from nearby rivers to be supplied to their fields. Hence, these canals will be used to channel water to the power house without disturbing irrigation to the agricultural fields. As shown in figure below wherein the community people of Toksel VDC are constructing power house for 3 kW system by channeling the water from Molung khola through the existing irrigation canal.

Furthermore, the villagers wish to use electricity for different commercial applications such as operating grinding mill, saw mill, and for community buildings like health post, school, and ward office. Hence, a hybrid system comprising of pico-hydro and solar can be installed wherein the hybrid system will provide power during peak loads in day time and the pico-hydro will fulfill the energy demand during nights.

Figure 1: Community people constructing power house

The project is scheduled to be completed by the end of November 2016. It is believed that the project will serve as a demonstration site for the dissemination of this technology in the relevant regions of Nepal. The project once completed will fulfill the required household energy demand. Additionally, other renewable sources of energy can be mixed in the forthcoming days to create hybrid system and the electricity thus generated can be distributed to the beneficiaries both for household purposes and commercial end uses.

CONCLUSION

There are many pico-hydro plants of different capacities installed by PEEDA which are running successfully for the past 3 years. The people in those communities have been satisfied and have shown their willingness to co-operate in the days to come. The ongoing project of pico hydro installation at Okhaldhunga district is targeted as a demonstration project for replication and for the development of similar projects in other parts of Nepal so that larger impacts could be realized with the involvement of different likeminded stakeholders. The demand for electricity is increasing day by day with increasing urbanization and modernization and thus simple captive load can be fulfilled with the pico-hydro installation. However, energy production to run commercial end uses is not enough through such technology; in that case hybrid technologies can be of importance. Hence such systems would largely fulfill the energy deficit in the rural areas of Nepal and can play a significant role in the socio-economic development of the rural communities deprived of electricity.

ENERGY MIX FOR ELECTRICITY GENERATION IN NEPAL

Kushal Gurung* and Rajan Tiwari**
*Chief Executive Officer, Wind Power Nepal Pvt. Ltd.
**Renewable Energy Officer, Wind Power Nepal Pvt. Ltd.
E-mail: info@windpowernepal.com

It would be a cliché to say that Nepal is blessed within enormous potential for hydropower generation. Widespread general knowledge is that we have at least 83,000 MW of hydropower potential, of which about 42,000 MW is commercially feasible. Although the first hydropower plant in Pharping generating 500 KW of electricity was commissioned in 1911 AD, Nepal has not been able to harness even two percent of its viable potential. With a mere electricity generation of about 840 MW which accounts to only about 50% of the total electricity demand, Nepal faces frequent power cuts every year, up to 18 hours a day during winter. Although, Nepal Electricity Authority (NEA), a state-owned and only utility company in Nepal, imports about 300 MW of electricity from India in order to reduce the long load shedding hours, still majority of population in the urban areas are using inverters and generators to cope with their electricity needs.

Though, NEA has concluded 185 Power Purchase Agreements (PPA) with various Independent Power Producers (IPP) with a combined generation capacity of 2800 MW in the fiscal year 2015/16, the realistic commercial operation of these projects will take another three to five years, depending upon timely completion of various projects at various stages of development and construction. Moreover, actual electricity demand of the country during the next five years' time will grow significantly and thus Nepal is still likely to face electricity deficits. In order to meet the ever increasing demand of electricity from the household and industries, the government of Nepal should look into other options that are quicker for energy mix for electricity generation to find quicker measures than hydropower to curb the load shedding hours. While importing more electricity from neighboring countries and constructing diesel power plants to generate electricity might seem like the easiest and quickest option to meet the current electric demands, overdependence on fossil fuels will eventually put Nepal at vulnerable position for energy security. In addition, importing a large amount of electricity and large volumes of diesel will create a trade deficit and also increase air pollution. Thus, Nepal should look into other clean renewable resources like solar and wind energy as a quicker measure to curb load shedding.

The solar and wind resource available in Nepal can play a significant role in curbing the current load shedding problem. According to the Solar and Wind Energy Resource Assessment (SWERA), a study conducted by Alternative Energy Promotion Center (AEPC) with the support of United Nations Environment Program/Global Environment Facility (UNEP/GEF), the global horizontal solar irradiance in Nepal stands at 4.7 kWh/m^2/day and thus opens a vast possibility of solar farms for electricity generation. Similarly, Nepal has a theoretical potential of producing about 3000 MW of wind energy. However, the development of solar and wind energy in Nepal is still at an infant stage. Although large solar and wind farms can be brought into commercial operation within a year, which is significantly quicker compared to hydro-projects, Nepal has not been able to tap into solar and wind resources due to the lack of supportive policies and incentives from the government. Unlike solar, wind is a localized resource but can outperform solar farms if built in a large scale with good wind velocity both in terms of capital investment and power generation; however is still in an infant stage due to the lack of wind resource data. In addition, other bottle necks for solar and wind farms include lack of stable transmission grid, road network and capital investment.

AEPC is working for the development of renewable energy technologies in Nepal with the help of various donors and private companies. However, in terms of electricity generation, the scope of AEPC lies only in areas with no access

to the national grid. Recently, they have been able to work in the urban areas too, as they have launched urban solar schemes to promote the use of rooftop solar. The World Bank Group is supporting Nepal to conduct a nation-wide wind resource assessment, through its Energy Sector Management Assistance Program. The project is being carried out by a Nepali company, WindPower Nepal in collaboration with Technical University of Denmark (DTU) and 3E Belgium. The three-year project will create a validated wind atlas of Nepal, which would be publicly available, thus providing much needed information to project developers, IPPs and investors for developing wind projects. However, in order to realize big wind projects, the government must get the house in order first. There should be access of transmission line grid and road network to areas with good wind profiles, as well as favorable policies for foreign investment and public-private partnerships.

Likewise, another piece of the energy mix spectrum for Nepal would be Bioenergy. Nepal being an agricultural country has abundant biomass and thus have a huge scope of electricity generation through biogas and biomass. According to the Forest Resource Assessment Project funded by the Finland government, 44.74% of the total area of Nepal is covered by forest out of which 82.68% lies outside the protected areas. Forest resources provide a unique opportunity for biomass gasification to generate electricity and can serve the isolated rural areas that are not yet connected to the national grid. In addition, agricultural bio-waste from households, vegetable and fruit markets and animal excreta are ideal for biogas generation, which can be utilized to generate electricity with the help of gas generators.

In conclusion, Nepal with vast hydropower potential should look into tapping the energy from hydroelectric projects in the long run. But to solve the acute shortage of electricity and prolonged power cuts, energy mix is one of the most prominent solutions, rather than importing all the deficit electricity from India. In order to promote energy mix, the government must have a multi-sectoral holistic approach through tailored policies, rules and regulations.

REFERENCES:

Hydroelectricity Investment & Development Company Limited, "Nepal Hydropower Overview". Accessed 26th Sept 2016, <http://www.hidcl.org.np/nepal-hydropower.php>

Nepal Electricity Authority, "Nepal Electrical Authority A Year in Review-Fiscal Year 2015/2016". Accessed 26th Sept 2016, <http://nea.org.np/images/supportive_docs/NEA%20design.pdf>

NEPAL ENERGY FORUM, "Pharping Hydropower Station". Accessed 26th Sept 2016, <http://www.nepalenergyforum.com/pharping-hydropower-station/>

Department of Forest Research and Survey, "Forest Resource Assessment Nepal (Main Results)". Accessed 26th Sept 2016, <http://www.dfrs.gov.np/downloadfile/main%20result_1470141289.pdf>

My Republica, "Nepal to import 80 MW more from Feb 17". Accessed 26th Sept 2016, <http://admin.myrepublica.com/economy/story/37132/nepal-to-import-80-mw-more-from-feb-17.html>

Investment Board of Nepal, "Energy Demand Projection 2030: A MAED Based Approach", Energy Mix and Electricity Demand Forecast Study. Accessed 26th Sept. 2016, <http://ibn.gov.np/uploads/files/Working%20Classification/reports/Energy%20Demand%20Projection%202030.pdf >

SWERA Final Report, "United Nation Environment Program Global Environment Facility Solar and Wind Energy Resource Assessment in Nepal (SWERA)", 2006.

DEPLOYMENT OF GRID-CONNECTED SOLAR PHOTOVOLTAIC IN NEPAL: THE OPPORTUNITY AND CHALLENGES

Jiwan Kumar Mallik

INTRODUCTION

The large scale deployment of Solar Photovoltaics is of rising interest both in the national and global context. In 2005, the global installed capacity of Solar PV was 5.1 GW, which had increased about 40 times by the year 2015 approximating the total global capacity to 227[1] GW of which 50 GW has been added last year only. Out of the total, China alone has approximately 45 GW of installed PV capacity followed by Germany at approximately 41 GW. The author believes that the 40 times increase over a decade in solar capacity is highest among the renewable energy technologies. This accelerated growth of grid connected solar PV signifies the importance of grid connected Solar PV system throughout the world.

In the context of Nepal, there is no official date of the first installation of solar PV in Nepal, however, it can be noted that Nepal Telecom was one of the first organization to install solar PV in the 1970's. After the establishment of Alternative Energy Promotion Center (AEPC) in 1996 with the main objective to promote alternative energy in Nepal, more than 700,000 off-grid solar home systems, approximately 2000[2] off-grid institutional systems mainly for schools, hospitals, FM stations etc. have been installed till date. Moreover, the first grid connected solar PV system of 1.1 kWp capacity was installed at Center for Energy Studies, Institute of Engineering (IOE) Pulchowk Campus on 31st October, 2012. The grid connected Solar PV installations of 3.3 kWp in Min Bhavan Substation of Nepal Electricity Authority and 1.1 kWp capacity at RIDS-Nepal (Rural Integrated Development Services – Nepal), Imadol, Lalitpur were completed on 20th December, 2012 and February 2013 respectively. These initiatives were taken by SUPSI Project in Nepal mainly for the research purpose. The data is monitored and recorded and then fed to a server that has a graphical user interface which can be seen on http://www.pvnepal.supsi.ch. So far approximately 820 kWp cumulative capacity of solar PV systems has been connected to the grid. The largest one is 680.4 kWp plant of Kathmandu Upatyaka Khanepani Limited (KUKL) at Dhobighat, Lalitpur installed in 2012 which was financially supported by Japan International Cooperation Agency (JICA). This plant was successfully commissioned on June 2012 and handed over to Government of Nepal on 11 January 2013. The Power Purchase Agreement (PPA) was signed between Kathmandu Valley Water Supply Management Board and NEA at the rate of NPR 5.10 per unit.

Photo: Grid Connected 680.4kWp Solar System in Dhobighat Lalitpur

[1] RENEWABLES 2016, Global Status Report, REN21

[2] Source: AEPC officials

THE STATUS OF GRID CONNECTION OF SOLAR PV IN NEPAL

The commercial grid connected solar PV system has been discussed by energy experts for more than 5 years in Nepal. The result oriented events including talks, seminars and workshops have been frequently organized since the former Prime Minister KP Sharma Oli announced that the government would build grid connected solar plants with cumulative capacity of 200 MW within a year. Immediately after the announcement, Ministry of Energy has formed two committees for the study of (i) Technical Feasibility of grid connected wind/solar system and (ii) PPA rate for grid connected wind/solar system.

The first committee has recommended that the maximum capacity of PV system which can be connected into Integrated Nepal Power System (INPS) is 15% of its total present generation capacity. The report further depicts that the maximum recommended size of solar PV which can be connected at different voltage levels are as described in table below:

Voltage Level	**Maximum Recommended Size of Solar PV for Grid Connection**
230 V	5 kWp
400 V	5-100kWp. However, above 40kWp there should dedicated transformer for Solar PV
11/33 kV substation	100kWp-5MWp
66/132 kV substation	Grid Impact Study is required

The second committee has recommended maximum benchmark Power Purchase Agreement (PPA) rate would be NPR 9.61 which is calculated on the basis of avoided cost. Avoided cost is the cost that the utility would have incurred had it supplied the power itself or obtained it from another source.

Moreover, The National Energy Crisis Mitigation Plan and Ten Year Electricity Development Plan 2016 have recommended that maximum 10% of present generation capacity can be connected to the INPS. It further says that 100 MWp solar can be connected to grid by next year considering that the generation would be 1000 MW by 2017 and 200 MWp solar sources can be connected by the next two years as there will be 2000 MW generation by then.

The preliminary finding of one study conducted by Institute of Engineering (IOE) Pulchowk Campus with the financial support from Asian Development Bank (ADB) has recommended that maximum of 60 MWp solar source can be connected in present context with maximum of 25 MWp can be connected at one point.

In the same way, National Renewable Energy Laboratory (NREL) of USA has suggested that in general, maximum solar capacity of 10-15% of total grid capacity can be connected to the grid. This study has been carried out by analyzing various technical matters.

Several studies have different recommendations about percentage of total generation capacity which would be technically feasible to connect to the grid. This causes a dilemma for policy makers, investors, market seekers and others associated. It is high time for Nepal to already have few grid connected solar projects in the range of a few MW rather than the authorities prolonging the argument about the percentage of solar capacity that can be connected to the grid. Considering the conclusions from the studies conducted in Nepal and other countries, the author believes that 10% of present total connected capacity of INPS would be a good choice. The reasons for limiting the power injection from intermittent source is described in successive section.

TECHNICAL CHALLENGES FOR GRID CONNECTION OF LARGE SCALE SOLAR AND ITS MITIGATION MEASURES

The grid connection of solar PV has been widely practiced in several countries. The grid compatible inverter technology is matured and smart enough to meet major technical criteria. Some of the major technical challenges which limit the penetration of Solar PV in the grid are discussed below.

Anti-Islanding- This is of primary concern to any utility. It is desirable that the solar PV system detects islanding condition within a fraction of second and isolates itself from the network. If it fails to do so, there is a chance that solar system back feeds to the network endangering line crew member and maintenance person or the solar inverter might even experience sudden increase of load (connected load in the network) and lead to damage of equipment itself due to overloading.

Inertia Constant- The inertia constant of solar inverter is negligible compared to hydro generator. Higher inertia constant can support higher reactive power requirement of the system during momentary fault condition. During momentary fault condition (say flashover of insulator which occurs for few milliseconds), if generators (solar inverter or hydro generator) fail to supply more reactive power then voltage drops and leads to black out. However, the smart solar inverters are capable of handling such kind of challenges. Smart[3] inverters can supply more reactive power during fault condition.

Fault Ride Through Capability- When Electric Power System is connected to the grid and disconnects at once, it creates a significant disturbance to the grid supply and would greatly reduce the power quality. Especially if it occurs in large number of installations, voltage fluctuation and frequency variation occurs; it may cause a reduction in power quality to other customers that are connected to the distribution line. To prevent this, a feature called FRT (Fault Ride Through) is added to prevent sudden disturbances in supply grid for continuing operation with some faulty conditions. Solar Inverters respond to both voltage and frequency variations much faster than conventional sources. However, it will only be able to supply rated kW or VAR it is designed to. In smaller inverters, a short duration of 5 times its rating is possible but in high power inverters, it is generally limited to 200% (2 times) of its rating at most.

Reactive Power Requirement- Many experts in Nepal argue that solar inverter cannot supply reactive power to the grid which is totally ridiculous. Some believe that solar inverter can supply reactive power to the grid only during the sunshine hours. This statement is also valid for some manufacturers. Many solar inverter manufacturers have listed the capability to supply reactive power during night time as one of the features in their inverters. In fact, the DC bus voltage inside the inverter should be kept constant which can be regulated from the grid supply then the reactive power can be adjusted according to the requirement. It is also important to note that for maintaining the DC bus voltage, active power from the grid is not consumed. Therefore, solar inverters have the flexibility to supply or consume reactive power as per grid requirement. Many solar inverters are designed to operate within the range of 0.8 lag to 0.95 lead power factor. However, the solar plant operator intends to operate it at unity power factor to fully utilize solar energy. This can be bonded with the grid code.

Low Voltage Ride Through- Solar inverters are capable to change the set point automatically to supply more reactive power during low voltage conditions.

Intermittency of PV generation[4] - The fluctuation of the output power of PV systems is one of the main factors that may cause severe operational problems for the utility network. Power fluctuation occurs due to variations in solar irradiance over the day. Power fluctuation may cause power swings in lines, over and under loadings, unacceptable voltage fluctuations, and voltage flickers. This is one of the major factors limiting the penetration of solar generation into the grid.

Cloud edging effect- Edge of the cloud with the sun behind it seems brighter leading to 25% increase in insolation (incoming solar radiation) temporarily. This may lead to large signal instability of the grid.

---

[3] http://spectrum.ieee.org/green-tech/solar/how-rooftop-solar-can-stabilize-the-grid

[4] http://www.academia.edu/2778282/Power_Quality_Analysis_of_Grid-connected_Photovoltaic_Systems_in_Distribution_Networks

Safety- It is one of the major concerns in PV systems due to unintended islanding at the time of fault occurrence at the grid side. Here, PV systems continue to feed the load even after the network is disconnected from the utility grid, which may cause electric shock to workers. Nowadays, solar inverters have inbuilt islanding detection techniques as per IEEE 1547 standard. Such solar inverters can isolate from the network within 2 seconds.

Power quality- Harmonic distortion is a serious power quality problem that may occur due to the use of power inverters that convert DC current to AC current in PV systems. The produced harmonics can cause parallel and series resonances, overheating in capacitor banks and transformers, and false operation of protection devices that may reduce the reliability of power systems. The standard inverter is designed to operate within total harmonic distortion of 5%.

WHY GRID CONNECTED SOLAR POWER IS GOOD OPPORTUNITY IN THE CONTEXT OF NEPAL?

In many of the events, the prominent hydro developers have been anticipating that load shedding in Nepal will be eliminated in the next few years. It is important to understand that most of the hydropower plants in Nepal are run-of-river type hydroelectric plants (HEP). These plants can only deliver about 40-50% of their installed capacities during dry season (November to April). Thus Nepal is forced to import electricity from India during that time. Even though there will be surplus generation in the wet season, there will be deficit in the dry season due to seasonal variation of water flow in the river. In this context, the power generation mix from sources like Solar and Wind plants can be a viable alternative to the import. If the added solar sources in the system lead to surplus during wet season, it can be exported or used in the other alternative purposes.

Since a typical solar plant can be constructed within a period of 12 months, it can mitigate the need of power deficit in a short time. This has also been recognized in the National Energy Crisis Mitigation Plan and Ten Year Electricity Development Plan 2016 that has emphasized on power generation mix like solar and wind.

It is calculated from various data sources that there can be 350 MWp Solar Power Generation equivalent to that produced from the storage capacity for peak time of peaking run of river HEPs. If the solar is implemented, these peaking run of river and storage HEPs can be utilized during peak load demand time.

The other beauty of distributed energy source like solar is that it can reduce transmission loss. A recently conducted study by Alternative Energy Promotion Center (AEPC) has shown that there is a total of 2,639 MWp potential of rooftop solar in residential, commercial and industrial categories in Kathmandu, Pokhara and Biratnagar Cities. Even if only some percentage of this potential is implemented, it will help to reduce transmission loss to a large extent.

CLOSING THOUGHTS

There is enormous opportunity to go for power generation mix in Nepal. This is right time to move ahead and connect MW sized solar PV system into the grid. The government should look into the constraints for issuance of license. Furthermore, the Government should also clarify the contradict clause mentioned in the Electricity Act regarding ownership of land after project life will be over. This is also one of the biggest hindrances to the promotion of grid connected solar PV in Nepal. Moreover, the government should also re-think on the benchmark PPA rate which has been set to NPR 9.61 per unit. A calculation has shown that Levelized Cost of Electricity (LCOE) of solar PV is around NPR 13.90 for 25 years of PPA period at 10% discount rate. Neupane et al, 2011 has found that LCOE cost of Diesel Generation used for commercial purpose in Durbar Marg is up to NPR 58.3. Thus it can be said that LCOE of solar generation is much lower than the cost of diesel generation. Thus, still NPR 13.90 LCOE of solar generation is justified. It is hard to believe that some of companies have quoted the benchmark PPA rate less than those in the NEA Request for Proposals (RFP) of 64 MWp that was announced recently. Let's wait and see the implementation of project which has been quoted less than NPR 9.61 PPA rate. Lastly, until the Government removes the aforementioned barriers, the future of solar PV inclusion into the grid can only be anticipated.

The author is currently working in the capacity of the Solar Power Expert with the UNDP-GEF supported Renewable Energy for Rural Livelihood (RERL) Programme under the umbrella of the Alternative Energy Promotion Center (AEPC) Nepal. The opinions stated in this article are his personal views and does not reflect that of the organization. He can be reached at jk_mallik@hotmail.com

SLOW DEVELOPMENT OF HYDROPOWER IN NEPAL: WHO IS RESPONSIBLE?

Prakash Sigdel
Environment Inspector, Department of Environment
Email: prakash.sigdel2000@gmail.com

It is not necessary to mention that Nepal is rich in water resources and there is a great possibility of hydroelectricity. Having a closed system of around six thousand rivers and rivulets, storing about amazing 224 billion cubic meter of surface water and having staggering mountain ranges that have mammoth volume of ice caps, we all know the challenges and possibilities of water resource management in Nepal. While discussing water resources, the term "hydroelectricity" cannot be ignored. Tremendous energy is stored in Nepalese rivers but we have been able to harness very less hydroelectricity.

Many of us might not know the fact that Nepal established second hydroelectricity project of Asia in Pharping way back in 1911 A.D. Though having a pioneer history in hydropower project construction, a large portion of the country (26%) is still not getting electricity from national grid and has to depend on other alternative sources of energy. It is shame on us to accept that the area, where national grid electricity is available, is forced to bear the chronic load shedding. Our rural communities are not getting adequate electricity. To access electricity in villages of Nepal is still national news. People are deprived to get electricity, which is a basic infrastructure for socio-economic development. What are the major problems and solutions?

CAPITAL MANAGEMENT

We do not have the problem of capital investment. To get certain share in Initial Public Offering (IPO) of banks worth certain million rupees, people sit in queue for hours and billions of rupees is collected in some days. This fact indicates the flow of money in our market. Real problem is capital management. We don't have any clear roadmap about managing scattered money in market, about managing remittance obtained in sustainable sectors such as hydropower. Although Nepal Rastra Bank launched some money market instruments, such as bonds, these schemes are primarily focused to address the problem of excess liquidity in the market. So Nepalese who have been abroad to earn money are not interested in these schemes. Even national commercial banks are also hesitated to invest the collected capital in hydropower sector. The banks are willing to invest in those sectors that can provide immediate benefits to them. It is obvious that the benefits from the hydropower sectors are not available overnight. Some time is needed to get results from the sustainable source such as hydropower. Although Nepal Rastra Bank has issued a provision that fixed ratio of the total capital should be invested in hydropower sector, this is not being implemented effectively. Until F.Y. 2072/73, it was estimated that about 100 billion rupees was invested in hydropower sector by commercial banks of Nepal. According to Department of Electricity Development, banks signed loan agreements with around one and half dozen small and big hydropower projects (1-100 MW) until May 2016. But that is also not enough to develop the hydropower projects.

TRANSMISSION LINE

Another major challenge in hydropower development is lack of adequate transmission line. It is equally important to construct transmission line along with hydropower projects. Without transmission lines, electricity cannot be transmitted to grids and the generated electricity cannot be accessed to the public. During monsoon season, generated electricity is in surplus in mid western region of Nepal due to lack of transmission lines. Due to lack of Khimti- Dhalkewar Transmission line, about ten-megawatt electricity generated from Khimti and Bhotekoshi hydropower projects is being wasted. Ambitious demands from local people, complexities in the land acquisition of forest areas, monopoly of Nepal Electricity Authority (NEA) in construction of transmission line are some causes of insufficient transmission line in Nepal. During the period of over hundred years, about 981 km of transmission line is established in Nepal. However, NEA is planning to expand its transmission line to 3272 kilometers or circuit. This includes 78 kilometers of 33 kV, 1409 kilometers of 132 kV, 755 km of 200 kV and 1030 kilometer of 400 kv in the coming ten years. Without transmission line, private investors are not willing to invest in hydropower. Even NEA cannot establish new projects without the adequate transmission line.

IEE AND EIA

One of the major blame put upon by concerned stakeholders is that the problem persists in policy level. Independent power producers frequently blame that the procedure for Initial Environmental Examination (IEE) and Environmental Impact Assessment (EIA) are lethargic and frustrating, concerned ministries add complexities in the process etc. That may be acceptable in some cases because concept of IEE and EIA are still in primitive stages in Nepal. Many attributes are to be clear regarding the environmental assessment. However, some facts should not be neglected. Until now, the focal ministry i.e. Ministry of Population and Environment has approved EIA report of 90 hydropower projects whose generation capacity is nearly fifteen thousand megawatt. Out of them, five projects are in operation and 10 projects are in construction phase. Similarly, out of remaining 75 projects, 19 projects are in the process of acquiring generation license and other procedures. Present status of remaining 56 projects is not known to the concerned agencies. If only EIA procedure was to be blamed, then all EIA approved projects would have been in construction or operation phases. That is not the case. There are different stages for hydropower construction such as acquiring survey license, generation license, financial closure etc. that may take some time. Therefore, it is not justifiable just to blame EIA procedure. There might be need to improve EIA procedures, but existence of EIA cannot be questioned, whatsoever.

WAY FORWARD

Hydropower sector, without any doubt, is one of the very few alternatives that can open the door to prosperity in Nepal. Suitable geography, sufficient water flow and adequate capital in the market are the attributes, which can be used to end the darkness and generate enough hydroelectricity to expand industrialization, tourism, agriculture and other infrastructures of development. Some of the legal and policy level uncertainties should be managed. Similarly, government should encourage its people to invest in sustainable sector such as hydropower and assure that investment in hydropower is a risk free investment. We are blessed by nature in one way or the other. All we need is a proper vision and clear cut target. Then only the chronic load shedding problem will be eradicated and we will be able to live in a cleaner and better country.

REFERENCES:

http://www.aarthikdainik.com.np/news_details/541/.html (accessed 8 September 2016)

http://www.spotlightnepal.com/News/Article/Transmission-Line-Challenges (accessed 8 September 2016)

http://www.nepalenergyforum.com/banks-invest-rs-80b-in-hydropower/ (accessed 11 September 2016

http://www.mope.gov.np/uploads/files/Approved%20EIA%20List%20of%20Projects%20till%20now%20(2073-4-26).pdf (accessed 11 September 2016)

http://www.doed.gov.np/operating_projects_hydro.php (accessed 11 September 2016)

http://ujyaaloonline.com/news/57841/?view=fullsite (accessed 12 September 2016)

https://thehimalayantimes.com/business/central-bank-float-rs-50-billion-worth-nrb-bonds-fiscal/ (accessed 14 September 2016)

HEALTH AND ENVIRONMENTAL BENEFITS OF ICS

Keshab Raj Joshi
Environment Inspector, Department of Environment
Email: keshabj@gmail.com

BIOMASS ENERGY

Traditional biomass energy is the major source of energy in Nepal. Consumption rate of traditional energy is still high despite the several efforts made towards using renewable energy (MoF, 2016). Traditional sources of biomass energy include firewood, cow dung and agricultural residues. Out of total energy consumption of 14,652.54 Tons of Oil Equivalent (TOE) in the fiscal year 2014/15, 62.13 percent share is that of traditional sources. That was 79.97 percent during fiscal year 2013/2014 (Table 1). Out of 5,423,297 households in Nepal, 4,033,350 households (74.37 %) use solid biomass (firewood and cow dung) for cooking (CBS, 2012).

Table 1: Energy Consumption Status of Nepal

Energy Source	Fiscal Year 2013/2014 (000 TOE)	Fiscal Year 2014/2015 (000 TOE)
Traditional	8983	9104
Firewood	8154	8264
Agricultural Residues	403	408
Cow Dung	426	432
Commercial	1958.96	5256.9
Coal	320	465
Petroleum Products	1264	4294.62
Electricity	374.96	397.28
Renewable	291	291.64
Total	11232.96	14652.54
	Source: MoF, 2016	

HEALTH RISKS

Biomass energy is mainly used in traditional stoves. Burning such biomass produces excessive smoke because of incomplete combustion releasing tremendous poisonous particles and various harmful chemicals. The smoke is contained with health damaging pollutants like fine particulate matter, carbon monoxide, nitrogen dioxides and poly-aromatic hydrocarbons (WHO, 2016). Such harmful chemicals when dispersed along with smoke around kitchen and home, people there always remain at risk.

Indoor air pollution was ranked as a fourth risk factor causing disease and death in developing countries with high mortality rates according to World Health Organization (WHO). WHO reports over 4 million worldwide human deaths every year only due to household air pollution caused by the inefficient use of solid fuels for cooking. Indoor air pollution associated with solid fuel use was responsible for the 7,500 human deaths each year in Nepal during 2002 (WHO, 2007). Indoor smoke causes lower respiratory infections, chronic obstructive pulmonary disease and trachea, bronchus and lung cancer. Indoor air pollution may also be associated with tuberculosis, cataracts, and asthma (WHO, 2002). Therefore, smoke from the traditional cook stove (TCS) has been identified as a killer in the kitchen.

Figure 1: Woman and children in kitchen with smoky TCS

ICS AS A SOLUTION

Out of solid biomass energy used in Nepal, firewood covers more than 90 percent (Table 1). The complete use of clean energy technology mainly in rural part of our country does not seem possible due to poverty. Rural households having cattle and capability to invest are using biogas. Still, they are using traditional stoves using firewood. Therefore, the situation of compulsory use of firewood suggests for the adoption of improved cook stoves (ICS) as a solution.

Improvement in the TCS with the adoption of efficient fuel burning technology, reduction in smoke emission or provision of outlet to emit smoke outside and increase in efficiency makes a stove as ICS. With simple technology, ICS is effective in reducing fuelwood consumption and cooking time and creation of smoke free environment. ICS is boon for the mitigation of indoor air pollution. Convenient in cooking process is the added advantage.

Figure 2: Rocket stove installation for demonstration and women carrying the firewood

Different types of ICS are used in Nepal. Out of them, two pot-hole mud stove is common as it is simple, less expensive and can be made from locally available material. For space heating purpose in cold region, metallic ICS are made. Similarly, institutional ICS is made for the places like public school, public hospital/health post etc. Another less fuel burning chimney less ICS is rocket stove which is also under dissemination in many places. These rocket stoves are also available in portable form with different brands and cost.

ICS installation requires arrangement of locally available materials in-situ and other non local materials are to be used with fixed design produced from accredited producers. Trained ICS promoters install ICS in a fixed design with the use of locally available and non-local materials. Subsidy is also provided to install ICS. Renewable Energy Subsidy Policy, 2073 (2016) has a provision to provide the subsidy for metallic ICS, full or partial metal body portable/rocket cookstoves and full or partial metal body gasifier system household cook stoves. However, there is no provision to provide direct subsidy for the promotion of household mud ICS and therefore, there is a policy of encouraging local bodies to provide financial support to install mud ICS to targeted beneficiaries (MoPE, 2016).

ENVIRONMENTAL CONSERVATION

Use of ICS contributes for environmental conservation. Because of high working efficiency, its use reduces fuelwood demand and consumption. Fuelwood reduction means forest as its source will be conserved. Likewise, indoor air pollution is reduced due to less firewood consumption and less smoke production or smoke outlet. Carbon emission is also reduced along with smoke emission from the reduction of firewood consumption. An ICS can contribute to around 1.5 tons of CO_2 emission in a year (CRT/N, 2014). It means that ICS use reduces greenhouse gas emission. Therefore, ICS promotion can also be done

through carbon emission reduction projects. Such projects are also under implementation in Nepal contributing towards ICS promotion and their effective use. ICSs also emit a considerably lower volume of particulates than traditional cooking fires and reduce black soot deposits from cooking smoke on the ice (INFORSE and CANSA, 2015). Therefore ICS contributes for mitigating climate change.

FAMILY HEALTH PROMOTION

Smoke reduction from stoves is an important way to improve family health (Conant and Fedem, 2012). More working efficiency of ICS reduces kitchen hours to cook thus reducing the kitchen time of cooking. Because of that there will be less exposure to smoke and fire which will reduce respiratory problems, fire risk and accidents of person in kitchen and family. Mainly, children will suffer less from pneumonia and women from asthma. Eye and headache problems are also reduced.

Figure 3: Woman using her new ICS

As ICS use reduces firewood consumption and cooking time as well as the blackening of utensils, woman with the kitchen responsibility has to input less time for firewood collection, cooking and washing utensils thus reducing the drudgery of women. Woman health improvement can also be expected due to less exposure to the smoke. Smokeless environment of kitchen may attract male members as well to share work load. Children can also be kept inside the kitchen indulging them towards study and entertainment activities.

CONCLUSION

Traditional sources of biomass energy still occupies major portion of energy consumption by fuel type in Nepal. Environmental degradation, indoor air pollution and associated family health hazards are the issues of traditional biomass energy use. It is necessary to contribute towards forest and environmental conservation making our kitchen healthy with the use of ICS. For this, it is necessary to install ICS in every households of Nepal using firewood for cooking and heating purposes. Coordination and cooperation of government agencies, donors and others stakeholders is necessary for the dissemination of the ICS. It is our duty and responsibility to save our health and contribute for the environmental conservation with the use of ICS.

REFERENCES:

CBS, 2012. National Population and Housing Census 2011(National Report). Volume 01, NPHC 2011. Central Bureau of Statistics. Kathmandu, Nepal.

Conant and Fedem, 2012. A Community Guide to Environmental Health. Hesperian Health Guides. California, USA.

CRT/N, 2014. Participation in Improved Cooking Stoves (ICS) Promotion Activities in Nepal for Rural Livelihood Enhancement and Mitigation of Climate Change. Centre for Rural Technology, Nepal. Lalitpur, Nepal.

INFORSE and CANSA, 2015. Eco-village Development as Climate Solution. Policy Brief. International Network for Sustainable Energy. http://www.cansouthasia.net/pdf_files/EVD/EVD%20Policy%20Brief%20COP%2021.pdf . Accessed on September 28, 2016.

MoPE, 2016. Renewable Energy Subsidy Policy, 2073. Ministry of Population and Environment. Government of Nepal.

MoF, 2016. Economic Survey-Fiscal Year 2015/16. Ministry of Finance, Government of Nepal.

WHO, 2002. World Health Report 2002: Reducing Risks, Promoting Healthy Life. World Health Organization. Switzerland.

WHO, 2007. Indoor Air Pollution: National Burden of Diseases Estimates. http://www.who.int/indoorair/publications/indoor_air_national_burden_estimate_revised.pdf. Accessed on September 28, 2016.

WHO, 2016. World Health Statistics, 2016: Monitoring Health for the SDGs, Sustainable Development Goals. World Health Organization. Switzerland.

http://www.who.int/heli/risks/indoorair/indoorair/en/. Accessed on September 28, 2016.

http://www.who.int/mediacentre/factsheets/fs292/en/. Accessed on September 28, 2016.

MODELING THE IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES WITH COMPETING DEMANDS: A CASE STUDY OF KALIGANDAKI GORGE HYDROPOWER PROJECT

Rakesh Sahukhal[1]*, Tri Ratna Bajracharya[2]
[1]Energy, Environment Research and Development Centre – Chabahil, Kathmandu
[2]Office of the Dean, IOE, Central Campus – Pulchowk
*Corresponding Author: rakesh.sahukhal@gmail.com

ABSTRACT

Climate change can have impact on the water resources and demands in water stressed regions with competing uses. The communities around Kaligandaki gorge hydro power project in Myagdi district of Nepal is similar in that respect as people in the region depend on the river flow for most of its rural and agricultural needs. Meteorological data shows increasing annual average rainfall with erratic annual percentage change in rainfall in the area. The mean and minimum temperatures are on a decreasing trend. WEAP modeling was done to analyze water demand and supply in the area based on discharge data of Kaligandaki river obtained from Department of Hydrology and Meteorology. The available data was calibrated from 2001 to 2003 with validation period of 2004 to 2007. Performance of the model was assessed through statistical measures of calibration with RMSE and R2 values. Two scenarios were created besides the base year scenario which were discharge decrement scenario and irrigation technology scenario. Analysis showed that a prioritization of demands will be necessary in the area in the near future for sustainability of water resources due to climate change impacts.

Keywords: Climate change, ROR, Hydro power, WEAP

Nepal's water resources are dominated by glacier fed rivers and streams. Hydropower represents Nepal's most essential water based infrastructure and since their development already clashes with other competing water uses namely rural and urban demands, agriculture and industrial development, proper planning needs to be done so as to ensure demands and supplies are met without stressing the already susceptible resources. Kaligandaki Gorge Hydropower is one of Nepal's larger upcoming hydropower project located in Myagdi district of Nepal. A typical peaking RoR project, Kaligandaki gorge hydropower provides an ample opportunity to study the impact of changing climatic parameters on water variability for the project and other basic water demands of communities around the area. This paper summarizes the implications on agricultural and domestic water demands of the VDCs in project area caused by development of Kaligandaki gorge hydropower project given the condition that water requirements of hydropower is met throughout.

1. BACKGROUND

There are three major river systems in Nepal of which Kaligandaki forms a large portion of the Gandaki river system. The Kaligandaki river source is at the Nhubine Himal Glacier in the Mustang region of Nepal at an elevation of 6,268 metres (20,564 ft) [1]. Kaligandaki Gorge Hydropower represents a typical run-off river type system like most other projects in Nepal. The proposed project component lies in left bank of Mustang and Myagdi districts covering its head works and certain length of tunnel alignment in Lete and Kunjo VDC of Mustang district whereas surge shaft, penstock alignment and Power house area is provisioned to be located respectively in Gadpar and Gharap of Narchyang VDC in Myagdi district. The zone of impact from Kaligandaki Gorge Hydropower project includes four VDCs, Lete and Kunjo in Mustang district whereas Dana and Narchyang in Myagdi.

Location	Myagdi
Project type	PRoR
Installed capacity	252 MW
Turbine	Pelton, Vertical axis-8
Net head	498.3 m
Catchment area	3570 km2
Design discharge	61.66 m3/s
Annual energy	1010 GWh
Overall efficiency	83.4%
Project cost	US$363.99 million
Transmission line	132 kV; 1.5 km long

2. OBJECTIVES

The main objective of this research project is to assess and recommend measures to negate the impacts of climate change on water resources with competing water uses like at project site of Kaligandaki gorge hydropower in Nepal. The specific objectives include:

- To analyze climatic data like temperature, precipitation and discharge to assess effects of climate on water availability.
- To model the water demand and supply challenges at the site of Kaligandaki Gorge Hydropower.
- To address water management challenges and develop a scenario for proper allocation of resource.
- To recommend options to make possible design changes to better accommodate climatic variation on the target hydropower.

3. METHODOLOGY

Climate Data Analysis: Daily rainfall data of three nearby stations (Jomsom, Lete and Ranipauwa) from 1985 to 2014 were used for analysis during the study. Secondary data of the rainfall were taken from Department of Hydrology and Metrology (DHM). Optimum number of stations required for the study was based on statistical principal that a certain number of rain gauge stations are necessary to give average rainfall with a certain percentage of error. The optimum number of raingauges (N) was obtained by the following equation:

$$N = (C_V/E)^2$$

Where,

E = allowable percentage error in the estimate of basic mean rainfall

Cv= coefficient of variation of rainfall based on existing raingauge station and it is determined as,

$$C_V = (\sigma/Pm) * 100\%$$

The standard deviation is given by:

$$\sigma = \sqrt{\Sigma (Pm - Pi)^2/n-1}$$

Where,

Pm = mean average annual rainfall values

$Pm = \Sigma Pi/n$

n = existing number of raingauges

Pi = normal annual rainfalls at existing raingauges

For accuracy in various practical purposes, three stations were taken minimizing the error to 5%.

% error (E)	Optimum no. of raingauges (N)
10%	1
5%	3
4%	4

For temperature analysis the maximum, mean and minimum monthly temperature data recorded at Lete station for the last 17 years were analysed. Monthly discharge data of the river from 2001 to 2007, measured at intake of the hydro power by Hydro Solutions Pvt. Ltd. was used for modeling and analysis purpose.

Modeling framework and input: The WEAP software is a data-driven system that is customized to a specific river basin through a graphical user interface.

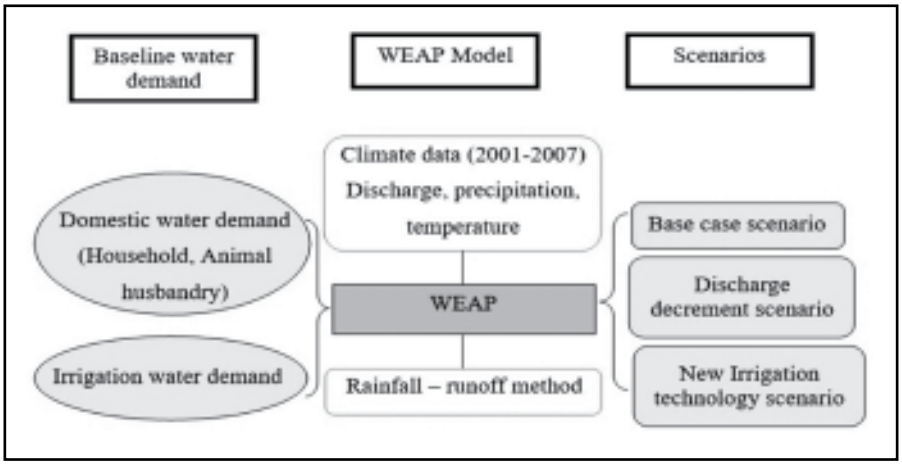


Figure 1: Model layout in WEAP

The WEAP model offers a choice of three methods to simulate basin hydrological processes namely irrigation demands only method, rainfall-runoff method and soil moisture method. Of these rainfall-runoff method was adopted because of availability of data for its successful implementation. Monthly discharge data from 2001 to 2007 at intake site of Kaligandaki Gorge Hydropower was used to calibrate and validate the WEAP model. For calibration, data from 2001 to 2003 was used to estimate the model parameters while the stability of these parameters was tested in the validation period of 2004 to 2007. Following modeling inputs under baseline scenario and calibration, water demand and supply for 20 years was simulated in WEAP while setting up the account. Through observation of the demand forecasts, other scenarios were setup for further analysis of the water situation in the research area.

Scenarios: Base case or reference scenario was set as 2007 as the final year flow data was available up to that year. Demands were projected for rural use by multiplying the population times per capita use rate. The population was projected to the year 2027 by using an annual growth rate of 1.2%. Therefore the rural demand increases throughout the analysis period. It was assumed that the area of the agricultural lands and the types of crop would stay the same for the purposes of the baseline scenario. Discharge data at intake for the base case 2007 was entered as monthly time series under river head flow. Discharge decrement scenario was developed to reminisce the A1 scenario of IPCC's report for policymakers which emphasizes a future of very rapid economic growth and population growth. This scenario models the changes in demand coverage due to decrease in river discharge in the future.

Discharge Decrement Scenario:

Parameters	Change value
Population Growth	1.50%
Irrigation efficiency	50%
Agricultural demand increase	5% per year

The new irrigation technology scenario was modeled after the B2 scenario of IPCC's summary report for policy makers which emphasizes is on local solutions to economic, social and environmental sustainability. This scenario was modeled based on the discharge decrement scenario by improving irrigation efficiency from 50% to 80% to simulate efficiencies that can be attained by sprinkler and drip irrigation methods. The irrigation water requirement was set as increasing at rates of 5% every 5 years, assuming increasing needs of food supply.

New Irrigation Technology Scenario:

Parameters	Change value
Population Growth	1.50%
Irrigation efficiency	80%
Agricultural demand increase	5% per year

Baseline data for modeling:

Per capita annual water use	890 m^3 [2]
Unit domestic water use	30.527 m^3 (3.43%) [2]
Unit irrigation water use	854.4 m^3 (96.16%) [2]
Domestic variation	0.9 for Jan, Feb and Dec; 1 for Mar, Apr, May, Sep, Oct; 1.1 for Jun; 1.15 for Jul and Aug
Monthly irrigation variation	2 for Jan, Feb; 5 for Mar, Apr, May; 10 for Jun; 15 for Jul; 20 for Aug; 25 for Sep; 4 for Oct, Nov; 3 for Dec
Irrigated land in Mustang	0.233 ha/household [3]
No. of households	Lete- 222 [4]; Kunjo - 174 [4]; Narchyang - 456 [4]; Dana - 484 [4]
Irrigated land area	Lete - 51.7 ha [4]; Kunjo - 40.54 ha [4]; Narchyang - 106.25 ha [4]; Dana - 112.77 ha [4]

4. LIMITATIONS

Limitations of the study include the following:

- Discharge data available for modeling was limited (2001-2007). Due to lack of validation, the base case was taken as the year of last available data instead of current date. Forecasts of the discharge could not be validated for current year due to lack of data.
- For WEAP modeling, lack of verifiable commercial and industrial water usage data in the project area meant only agricultural and domestic demands have been considered. Lack of economic data meant scenarios based on A1 and B2 scenarios of IPCC were only modeled.
- The study is based on the secondary data from the concerned agency; the validation of the data depends on the organizational competence. Budgetary and time constrains to conduct an in-depth study.

5. RESULTS & DISCUSSION

5.1 CLIMATE DATA ANALYSIS

Precipitation: Nepal receives nearly 80% of annual precipitation during the months of June-September in most locations [5]. Distribution of rainfall around the Kaligandaki gorge hydropower project area is not uniform either. Elevation as well as exposition of mountains within the area plays major roles for uneven rainfall distribution. The 30 years of daily data available (1985-2014) for the area near the project site shows that 62% of rainfall occurs in monsoon with 25% in pre-monsoon followed by 8% and 5% in post-monsoon and winter respectively.

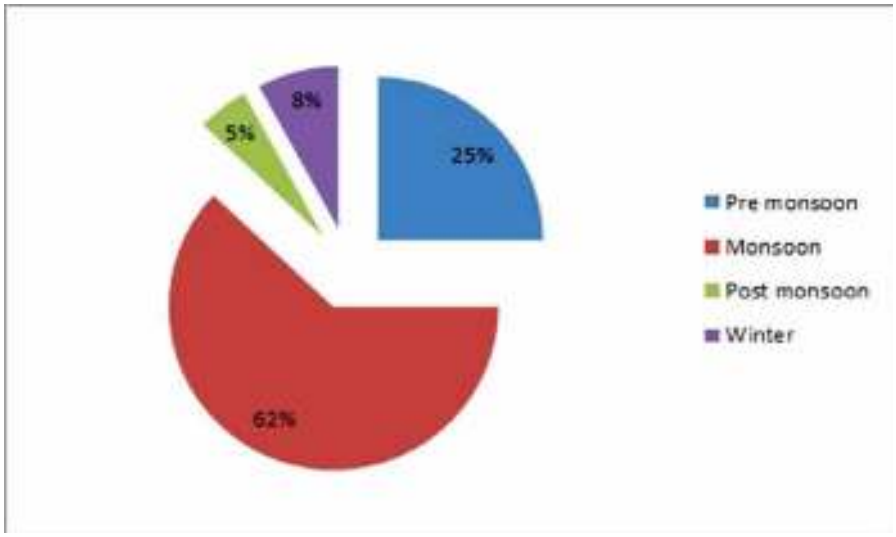


Figure 2: Seasonal rainfall distribution at Lete (1985-2014)

In a PRoR project like Kaligandaki gorge project, electricity generation will vary as per precipitation patterns, which means dry seasons may require a substitute source for the demands to be met. In a reservoir based hydropower station like Kulekhani however, usage of water accumulated during monsoon accommodate for electricity generation throughout the year. As illustrated by the graph below, precipitation around the project area peaks up from June to August and is highest during July. Winter months beginning from November and ending in January receives the lowest amount of precipitation.

The monsoon normally starts in the second week of June and continues until the fourth week of September. Monsoon is the main source of rainfall in the project site similar to other regions of Nepal. The large amount of rainfall within a short period causes flash floods, landslides, soil erosion and sedimentation in hilly and mountainous regions, and inundation of the plains areas [6].

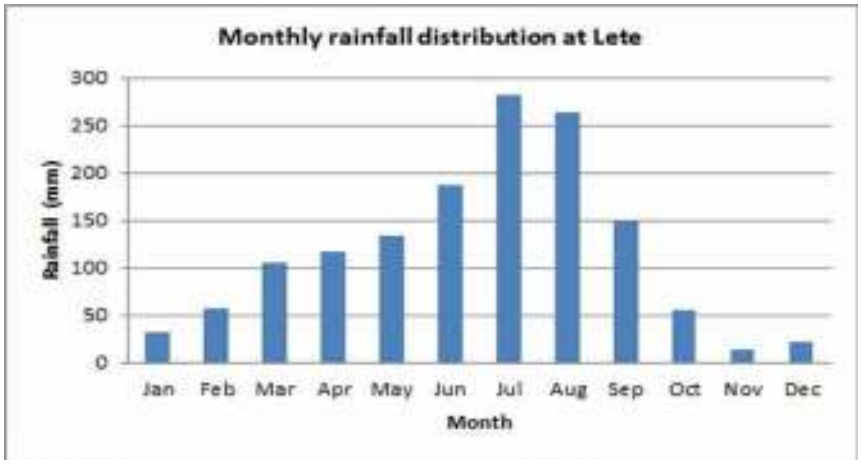


Figure 3: Monthly rainfall distribution at Lete (1985-2014)

There is no significant change in annual precipitation in Nepal [7]. This study shows that the annual average rainfall around the Kaligandaki project site is increasing at a slight rate of about 0.284 mm measured at Lete station. This concurs with slight increase in precipitation rate as seen in study based on data from Andhi Ghat Station, Mustang [6].

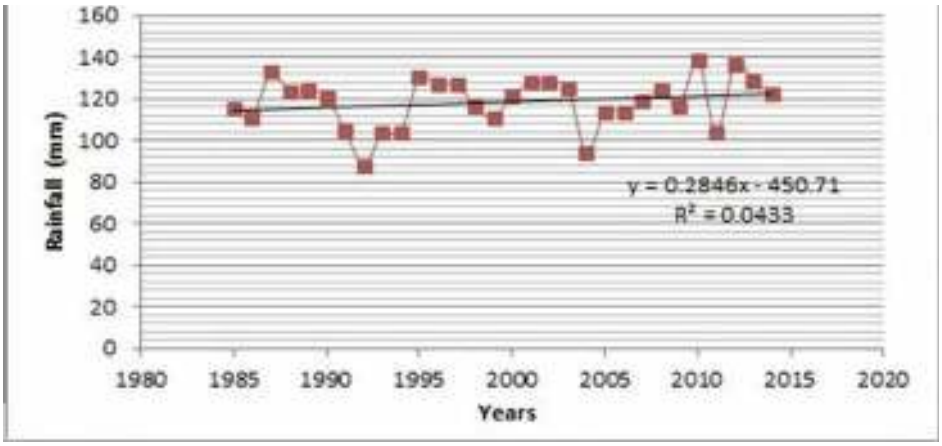


Figure 4: Annual average rainfall trend at Lete (1985-2014)

Temperature: Annual temperature in Nepal is reported to be increasing and the impacts of warming have already been observed in the Himalayan glaciers [8]. Annual mean temperature in Nepal has increased steadily at a linear rate of 0.4°C per decade from 1975 to 2005 [7]. Temperature data measured at Lete station (1998-2014) shows a decreasing minimum and mean annual temperatures. The maximum temperature is increasing, albeit very slightly.

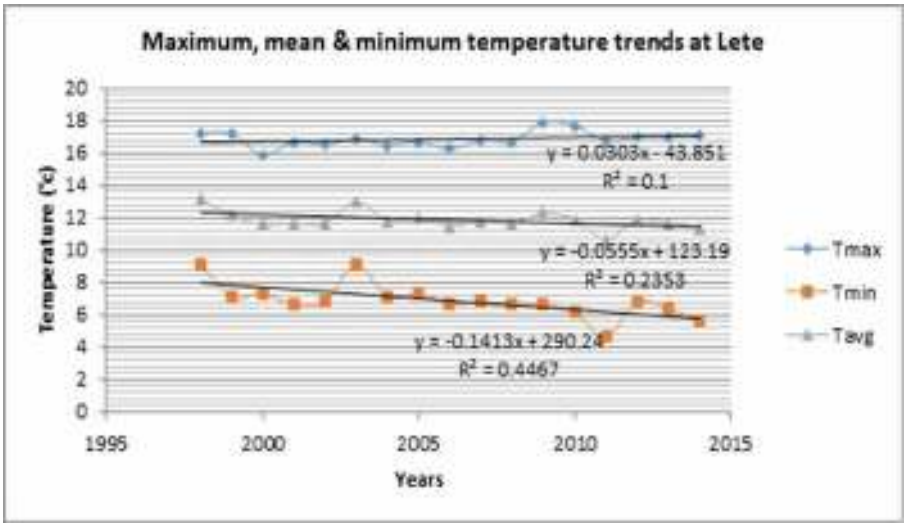


Figure 5: Annual temperature trend at Lete (1998-2014)

5.2 WEAP Modeling

Discharge Calibration: The period of 2001 to 2003 of the discharge data were used for calibration of the model with validation period of 2004 to 2007.

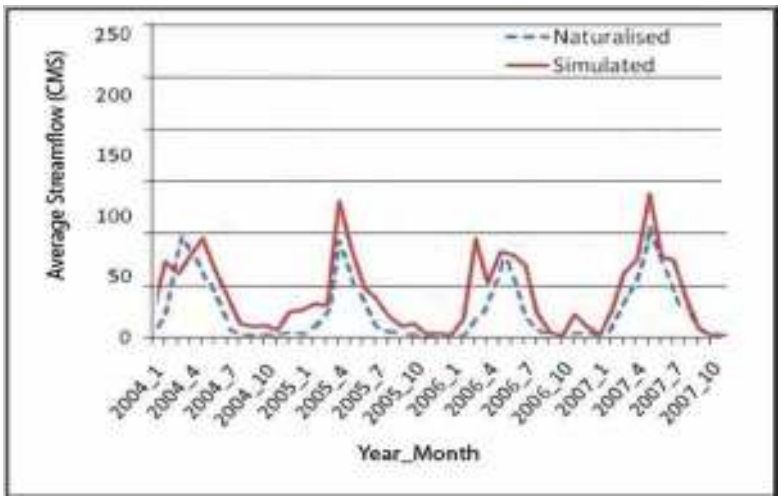


Figure 6: Calibration of discharge in WEAP

EFFICIENCY CRITERIA RESULTS FOR MODEL VALIDATION

The analysis showed RMSE% and R2 were 0.046% and 0.79 for discharge respectively. The trend of simulated discharge is reasonably close to the trend of observed discharge and both the calibration and validation periods show a similar fit to the data. However, there are some differences in the observed and simulated values. The reason for these deviations might be errors in the amount and distribution of precipitation over the watershed, or errors due to other factors that the model did not account for.

Modeling results: Following calibration of available stream flow data, projections were made for 20 years up to the year 2027. The discharge of Kaligandaki gorge is in a decreasing trend which is particularly noticeable following the year 2014. In 2027, discharge during peak monsoon month i.e. August is only 84.3 m^3/s compared to 133.3 m^3/s during the baseline year. This can be attributed to reduction in glacier melt and the decreasing precipitation trend.

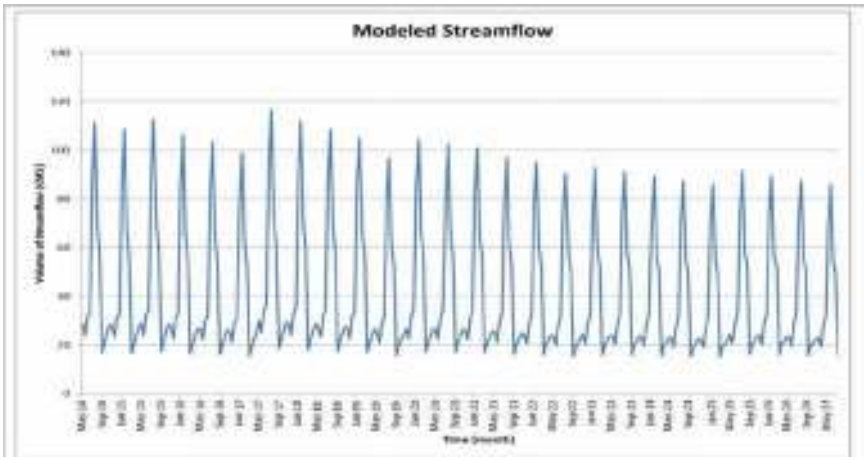


Figure 7: Modeled streamflow in WEAP

The total water demand for base case 2007 is 400 thousand cubic meters. Agriculture is the most water intensive demand since it alone requires more than 250 thousand cubic meters, the rest of demands being for domestic uses in the four VDCs. There is a general incremental trend in demands from base case to final year 2027. This is expected due to the population growth (1.2%) variation entered during scenario development. The final year water demand is more than 456 thousand cubic meters. The agricultural demand at this point is over 265 thousand cubic meters. Under current base case scenario, the demand coverage for both domestic and irrigation needs were met at 100. The domestic needs in the area include water demands for household purposes and animal husbandry. The animals regularly farmed or herded are buffalo, pigs, goats and sheep.

Regular crops grown in the area include maize, millet, wheat, potatoes. These basic crops are not so water intensive compared to other crops which are grown in the area like rice, chilies, onions, garlic, pumpkin, squashes and salad crops. The most water intensive crops grown in the area include citrus fruits especially oranges, apples, pears and mangoes.

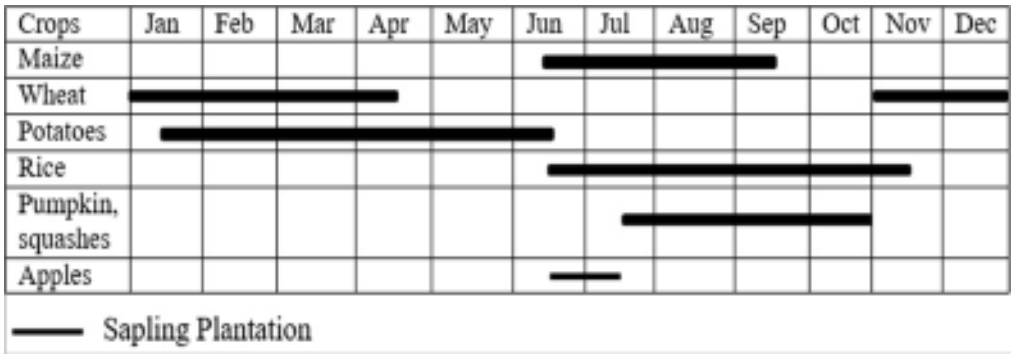


Figure 8: Crop calendar followed in the project area

Under discharge decrement scenario, the population growth factor has resulted in subsequent growth in domestic demand. The agricultural water demand is increasing as well due to increment of irrigation in needs by 5% per 5 years.

In terms of demand coverage, agriculture faces a shortfall in supply from the year 2019 during the month of September and October, when water intensive crops are planted. Also because agriculture has a supply preference of 2, when there is water shortage, domestic demand will have higher prioritized demand, assuming they are both demanding water at the same time. Thus though the domestic demands are being met, agriculture falls short in supply by about 15% for the month of October in the year 2027.

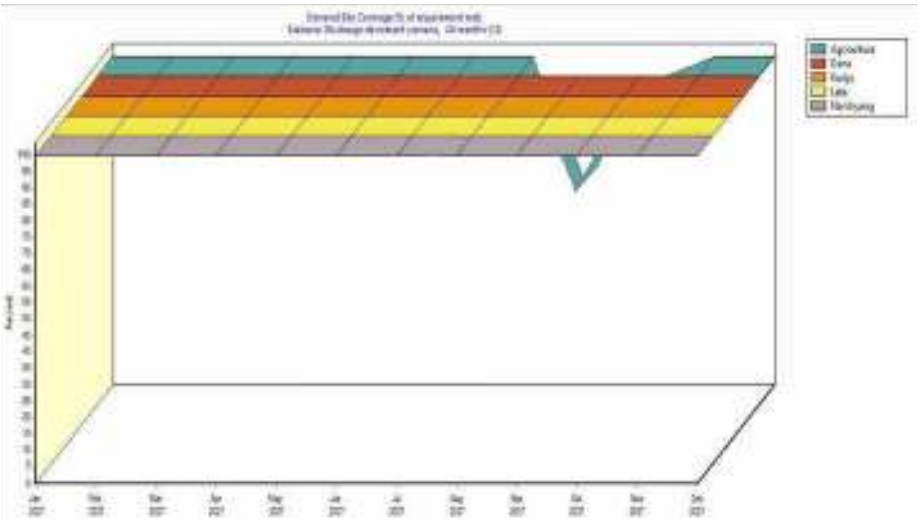


Figure 9: Demand site coverage in discharge decrement scenario for 2027

The total agricultural demand for the region under discharge decrement scenario for the year 2027 is over 664 thousand cubic meters. A 15% deficit in the demand for august shown in the figure 9 translates to a deficit of around 12 thousand cubic meters. For the month of October 2027 total unmet demand is around 4500 cubic meters.

Most of the water intensive crops are grown during the months of August, September and October in the area which has resulted in the more water use during these months.

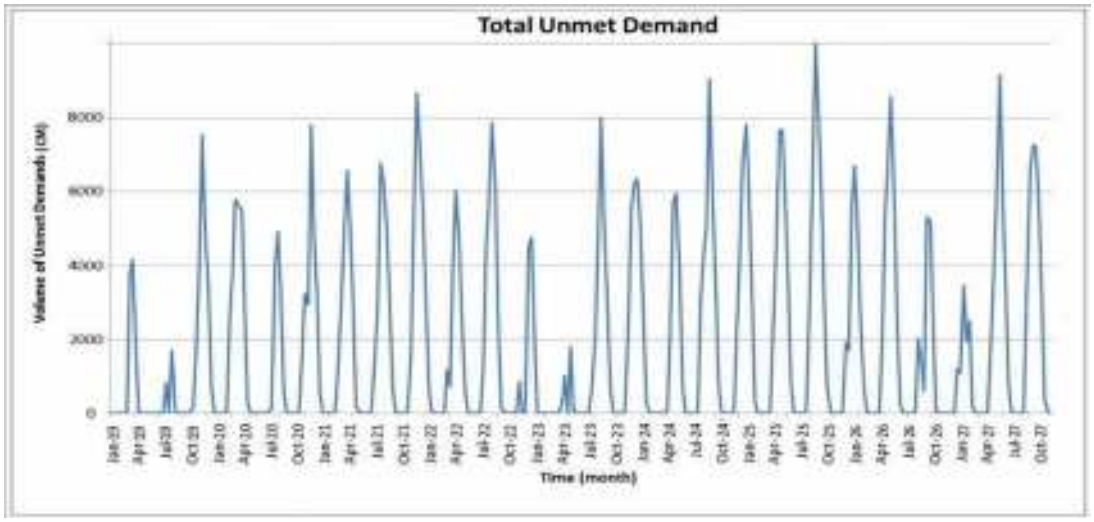


Figure 10: Total unmet demand in discharge decrement scenario up to 2027

The analysis of potential climate change scenarios has demonstrated the possibility for less stream flow to be available to meet increasing demands. The simulations show that the projected demands are not being met and the shortages can be large. The range of unmet demands is limited due to lower inflows and higher demands. In order to prevent large failures in the water resources system, decision makers and water managers will need to explore adaptation of their current water management practices to mitigate the negative effects of less available water resources. In this research study a single new irrigation technology scenario was introduced.

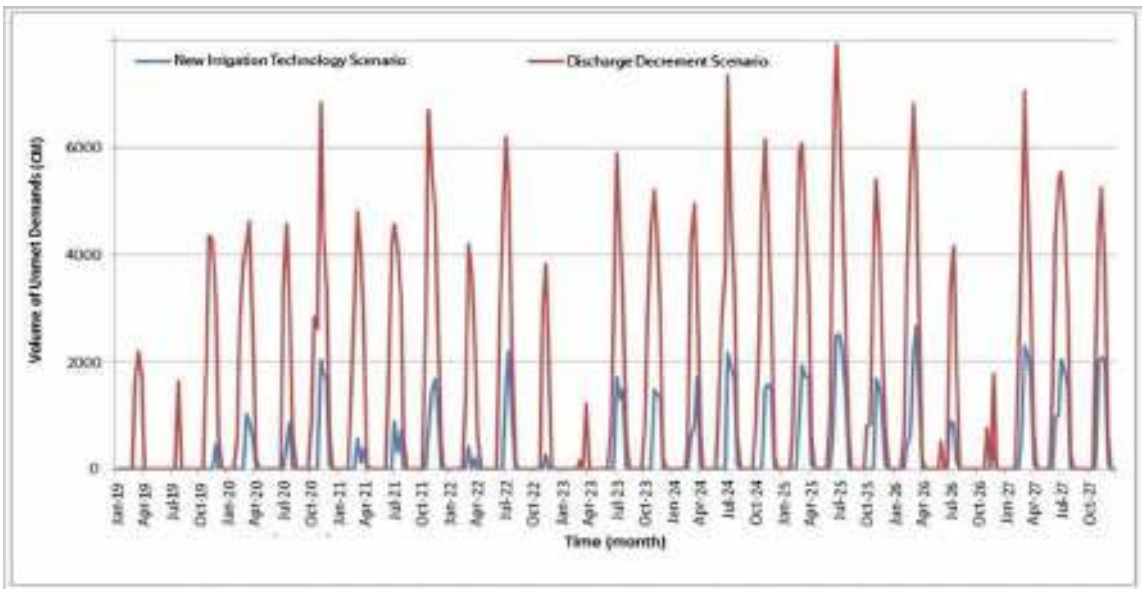


Figure 11: Total unmet demand in new irrigation technology scenario

New irrigation technology scenario sees an increase in previous irrigation efficiency of 50% to 80%. Such a technology may be either sprinkler or deep root drip irrigation technology. In comparison to discharge decrement scenario, the agricultural demand is decreasing in this new scenario, assuming such is the impact of new smart irrigation practices. The annual irrigation demand for the base case 2007 is same as above scenario which is 250 thousand cubic meters. The final year demand is about 478 thousand cubic meters which is a radical drop from the discharge decrement scenario demand of 664 thousand cubic meters.

In discharge decrement scenario, total unmet demands for the year 2027 were 4% of the total agricultural demand. Of the 17 thousand cubic meters unmet demand 4500 cubic meters was for the month of October alone. In the new irrigation technology scenario the deficit for October 2027 has reduced to around 2000 cubic meters. The deficits are not completely negated as the population growth for the scenario (1.5%) is more than the current growth rate of 1.35% and the increment of agriculture is 5% per year. On top of that the model predicts a decrement of discharge as well. Nonetheless the unmet demands have shown a positive response due to introduction of new technology.

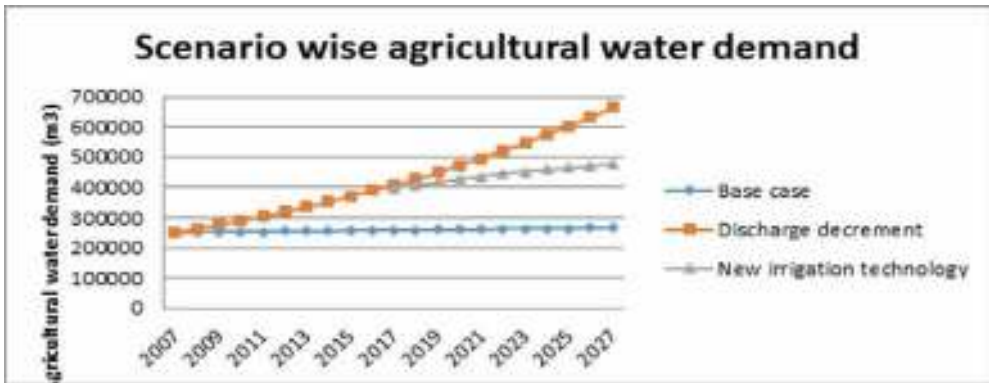


Figure 12: Total agricultural water demands in different scenarios

Under the discharge decrement scenario, the 5% increment in agricultural demand means the water demand is in upward increasing trend. The projected water demand for the year 2027 is 664,757 m^3 which is significantly greater than the 266,009 m^3 water demand seen under base case scenario. Introduction of a new irrigation technology that improves the overall irrigation efficiency from 50% to 80% comes into practice from 2017. There is a general decrement in annual irrigation demands from here on. The annual irrigation water demand for the year 2027 is 478,317 m^3 which is significantly lower than the demand in discharge decrement scenario. In new irrigation technology scenario, the annual unmet demand for the year 2027 is 17,450 m^3 which is significantly lower than the unmet demands of 29,943 m^3 in discharge decrement scenario.

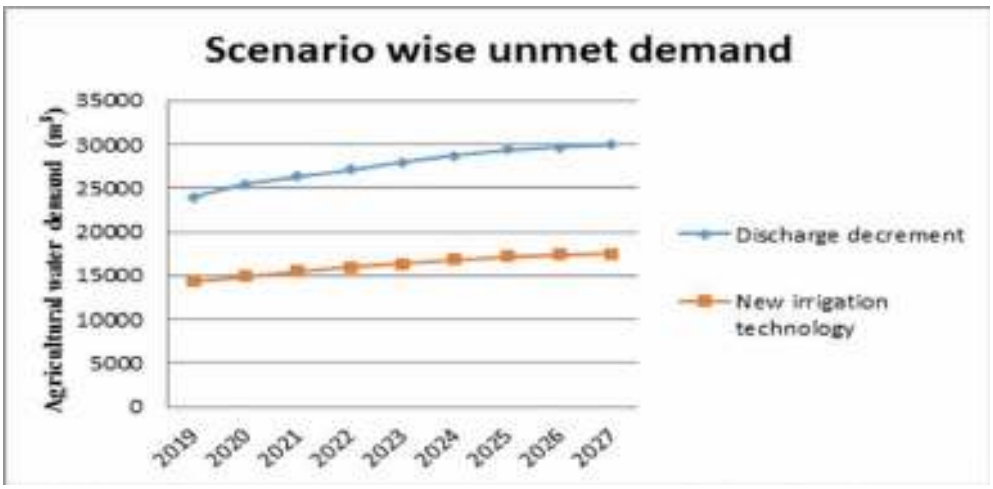


Figure 13: Total unmet water demands in different scenarios

The results of the simulation for the new irrigation technology scenario indicate that improving irrigation efficiency show lower values of unmet demand indicating a reduction in water stress in the agricultural sector. It should be noted that this mitigation scenario will last less than 5 years (under the best case for implementation) and might be considered to be insignificant.

The integrated water strategy has placed three phases of strategic goals for development of water related infrastructures in Nepal upto the year 2027. One of the outputs of the strategy is to develop efficient irrigation for optimal use of irrigable land in Nepal. Projections under this strategy show that by 2027 the irrigation demand will grow by 185% from 13 million m^3 in 2002 to 37 million m^3 (Thapa B. B., 2007). Under the new irrigation technology scenario, the annual irrigation demand of 250 thousand m^3 has risen to 478 m^3 which is a growth of around 190%.

6. CONCLUSION

The flow curve of the analyzed period and rivers shows the flow is decreasing and not in a pattern. Forecast of the year 2027 showed a sharp decline in discharge which will have acute repercussions in water supply for communities' needs as well as the hydropower. Change in hydrology of rivers is seen as a major impact of climate change resulting in anomalies in hydro resources which could be critical to areas of competing water uses. The minimum and mean temperatures of the site show decline of 0.05°C and 0.14°C respectively though the maximum temperature is increasing albeit very slightly (0.001°C).There is a general increasing trend in precipitation of about 0.284 mm. However percentage change in rainfall shows erratic nature of rainfall or shift in rainfall seasons which increases the hydrological impacts and challenges. WEAP model developed for the research site, taking into consideration the agricultural and domestic demands shows increasing demands due to population growth and anthropogenic activities. Total water demand in reference (base case) scenario for 2027 is 457 thousand cubic meters of which agricultural demand alone is over 266 thousand cubic meters. Under discharge decrement scenario, this demand increases to 664 thousand cubic meters of which there are deficits of over 29 thousand cubic meters. Under new irrigation technology that increases the overall agricultural efficiency from 50% to 80% the annual agricultural demand is 478 thousand cubic meters and the unmet demand is reduced to 17 thousand cubic meters. Introduction of a new technology has proven efficient in reducing overall agricultural demand that would otherwise go significantly unmet. However large scale immediate implementation of such technology is a difficult practice.

7. RECOMMENDATION

The rainfall distribution around the region is very uneven and basin has insufficient gauging systems. Discharge and rainfall recording network should be increased for intensity data that are most essential for hydrologic models and other detail hydrological study. Limitation of data meant only domestic and agricultural needs of the communities were considered in modeling. Nevertheless the model shows potential short supply situation in the future. Mitigation measures to avoid such occurrences include adoption of new technologies and prioritization of supply. Change in hydrology of Kaligandaki river means reservoir storage in hydropower site is a good option to ensure supply for hydropower systems as well as demand of nearby communities. The communities could use the water from the reservoir for both their domestic and irrigation needs while, it would also ensure minimum level required for hydropower operation.

REFERENCES:

[1] Ganesh Bhandari. The kali gandaki — all about Mount Everest and Nepal, 2011.

[2] Ashutosh Shukla, Uttam Raj Timilsina, and Binod Chandra Jha. Wastewater production, treatment and use in nepal, May 2012. UN-Water Information System.

[3] AIMS. District profile (draft) mustang. Technical report, Ministry of Agricultural Development, 2015.

[4] Hydrosolutions (P) Ltd. Hydrology report kaligandaki gorge hp. Technical report, Hydrosolutions (P) Ltd.

[5] Nepal Climate Vulnerability Study Team. Vulnerability through the eyes of vulnerable: Climate change induced uncertainities and nepal's development predicaments. Technical report, NCVST, 2009.

[6] Tri Ratna Bajracharya, Samanta Acharya, and Bhakta Bahadur Ale. Changing climatic parameters and its possible impacts in hydropower generation in Nepal (a case study on gandaki river basin). Journal of the Institute of Engineering, Vol. 8, No. 1, pages 160–173, 2011.

[7] APN. Enhancement of national capacities in the application of simulation models for the assessment of climate change. Technical report, Asia Pacific Network for Climate Change, 2007.

[8] ADB. Climate change assessment. Technical report, 2009.

AN OVERVIEW OF WASTE AND WASTE TO ENERGY PLANTS (WTE)

Tapendra Chand
Project Officer, People, Energy & Environment Development Association (PEEDA)
E-mail: tapendra@peeda.net

INTRODUCTION

Waste to Energy (WtE) or Energy-from-Waste (EfW) is the process of creating energy in the form of electricity or heat from the incineration of waste source which is indeed a form of energy recovery. There is large amount of solid waste generated worldwide which can be used as an essential raw material in establishing waste to energy plants. Statistical records show that the generation of municipal solid waste is increasing in substantial amount worldwide, specially, in developing countries where the population and consumption of goods is increasing rapidly. It has been estimated that by 2025 the daily municipal solid waste (MSW) generation rate in Asia would be 1.8 million tonnes per day. The OECD countries generate 572 million tonnes of solid waste per year (Daniel & Perinaz, 2012). The waste generation scenario in developing countries is different than in developed countries. The per capita waste generation in developing and underdeveloped countries is lower (about 0.5 kg per day, case of Nepal) than that of developed countries (about 1.47 kg per day, case of Japan) due to lower per capita consumption of goods and lower economy (Chandrappa & Das, 2012). However, total quantity of waste generated in developing and underdeveloped countries is substantially high because of the high population. For example, the daily waste generation of New Delhi is about 6500 metric tons whereas that of San Francisco is only about 1369 metric tons per day ((Asnani, 2006), (Gokaldas, 2012)). Further, the rate of increase in solid waste generation in developing countries is very high because of their increasing trend of economic activity, population and per capita consumption. In the big developing economies like China and India, whose population is also among the highest in the world, there is large amount of solid waste generated and that needs an appropriate waste management system like WtE. This scenario of waste generation quantity in developing countries shows a large potential of WtE system development in those countries.

TRENDS IN WASTE COMPOSITION

There is a significant variation in the composition of solid waste generated wherein low-income countries have an organic fraction of 64% compared to 28% in high-income countries (Daniel & Perinaz, 2012). This is the major challenge for the developing and underdeveloped countries for the development of WtE plants in the sense that they have to use the efficient and cost effective technologies suitable for the waste containing large amount of organic material which has low calorific value.

WORLD SOLID WASTE DISPOSAL SCENARIO

Large portion of the municipal solid waste generated is disposed on sanitary landfills and in open dumps which are widely followed practices worldwide. Sanitary landfills are more in practice in developing countries than in developed countries. Very small portion of the total waste generated is consumed in incineration or WtE systems even in developed countries like Europe and America. However, increasing alternative energy demands, strict environmental regulations, decreasing availability of suitable landfill area etc. are leading the waste disposal practice of the world towards efficient energy recovery systems like WtE systems. The development of WtE plants is widely spreading worldwide. About 231 million tonnes of municipal solid waste (MSW) are combusted annually by more than 800 WtE plants in nearly 40 countries around the world including large countries such as China and small ones such as Bermuda (Martin, 2012). The use of WtE plants in waste disposal is being popular even in the developing and underdeveloped countries. A typical waste to energy plant (WtE) with its components is shown in figure 1.

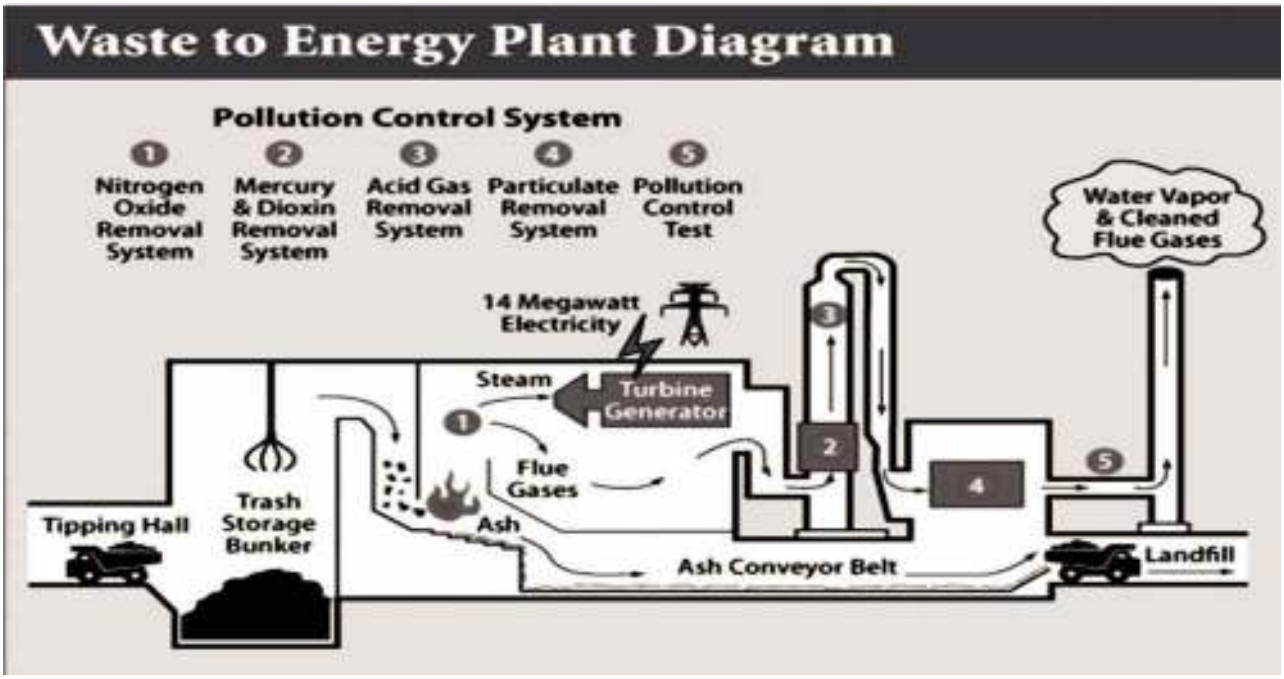


Figure 1: A typical waste to energy plant (WtE) (combs, 2008)

POSSIBILITY OF WTE PLANTS IN DEVELOPING AND UNDERDEVELOPED COUNTRIES

Earlier, we talked about the waste disposal scenario and the composition of waste in the developing and under-developed countries with comparison to some great economic tycoons of the world. Even though, the composition of waste (with maximum organic content) doesn't look promising but the quantity of waste generated give some possibilities for the so called waste incineration plants. Now, if we talk about the possibilities then it is better to talk with technical, economic and environmental perspective. The technology that is used in these countries is basically stoker grate system and fluidized grate system (with reference to India & China). Stoker grate system (also called mass incineration system) involves mass burning of as "received" and inhomogeneous waste and requires little or no pre-treatment. Since, it can accommodate large variations in waste composition and calorific value and requires less technical manpower for its operation, it is suitable technology for these countries and is thus positive aspect for its nourishment and development. Another technology that is used basically in China is fluidized grate system which uses 10-15% coal with prepared refuse or refuse- derived fuel (RDF) where RDF is the final product obtained (containing only Plastics and paper) after consequent separation & classification of inhomogeneous waste (Nelles, Dorn, Wu, & Cai, 2011). Since, this technology requires meticulous screening of waste; it requires more manpower and cost thereby increasing the total cost. However, it could be better option for carbon trading in these countries as it emits fewer amounts of greenhouse gases. In terms of economic perspective, its initial investment is high (for example; it took 45 million US dollar to establish 16 MW waste incineration plant in Timarpur, Delhi (Shah, 2011) but one of the fascinating thing is cost per unit which is only INR 4-5/KWh as in the case of Maharastra's Solapur WtE plants of 3 MW capacity (Babele, 2015). Even, there are lot of possibilities for funding via governmental budget, foreign aid and public private partnership.

Let's talk about Kathmandu valley, the capital city of Nepal that comprises of five municipalities (Bhaktapur, Kathmandu Metropolitan City, Kirtipur, Lalitpur and Madhyapur Thimi), which produces in average 620 tons of solid waste every day (ADB, 2013). In India, the average net calorific value or the amount of heat released during combustion of dry solid waste ranges from 800 kcal / kg to 1000 kcal / kg, with average value of 900 kcal / Kg (Pinak & Geeta, 2011). Since, the waste composition of Nepal and India is almost similar, the calorific value is similar. Hence, the total electricity that can be generated with 620 tons of solid waste in Kathmandu valley is nearly equivalent to 7 MW. At the moment, the waste management is done by open land fill which is frequently causing problems as far as health, environment and economic perspectives are concerned. So, recently Kathmandu Metropolitan city has decided to generate 14 KW of electricity from waste by mid October 2016 which will initially be used

for its office premises and will be replicated in other municipalities in the forthcoming days ((TANDAN, 2016), (Himalayan News Service, 2016)). Finally, let's talk from the Environmental Perspective which is really fascinating as WtE plants conserve fossil fuels (1 ton of MSW can conserve 1 Barrel of oil and 0.25 tons of coal) and thus helps in the reduction of Green house gas emission. Even it has been estimated that one ton of MSW combusted rather than land-filled reduces greenhouse gas emissions by 1.5 tons of CO_2. WtE plants can reduce the space required for landfilling by about 90% thereby reducing the emission of methane which is 20 times more harmful than CO_2 (WTERT). But, we can't ignore the fact that there are number of reasons that are obstacles to its development. One common problem is obviously its organic content (lower calorific value) as according to World Bank, the average calorific value should be at least 7 MJ/kg, and must never fall below 6 MJ/kg in any season. The other problem is hindrance from public either due to lack of knowledge regarding Waste hierarchy (Unable to distinguish priority of WtE-plants) or due to misconception regarding the emission of harmful carcinogenic toxins namely Dioxins & Furans. However, the merits that do exist from waste incineration plants surpass the existing demerits and thus it seems quite promising, pragmatic and futuristic technique for power generation in the developing and under-developed countries where power is essential for its economic development.

REFERENCES:

ADB. (2013). Solid Waste Management in Nepal: Current Status and Policy Recommendations. Retrieved from http://www.adb.org/sites/default/files/publication/30366/solid-waste-management-nepal.pdf

Asnani, P. U. (2006). Solid Waste Management. In A. RASTOGI (Ed.), INDIA INFRASTRUCTURE REPORT 2006 (pp. 160-189). New Delhi: Infrastructure Development Finance Company.

Babele, P. (2015, June 5). How Solapur converted garbage into electricity. indiatoday. Retrieved from http://indiatoday.intoday.in/story/solapur-converted-garbage-into-electricity/1/442470.html

Chandrappa, R., & Das, D. B. (2012). Waste Quantitites and Characteristics Solid Waste Management (pp. 47-63): Springer-Verlag Berlin Heidelberg.

combs, S. (2008). The Energy Report. Retrieved from http://comptroller.texas.gov/specialrpt/energy/pdf/96-1266EnergyReport.pdf

Daniel, H., & Perinaz, B.-T. (2012) WHAT A WASTE: A Global Review of Solid Waste Management. Washinton, DC 20433 USA World Bank.

Gokaldas, V. (2012). San Francisco, USA: Creating a Culture of Zero Waste. Retrieved from http://www.no-burn.org/downloads/ZW%20San%20Francisco.pdf

Himalayan News Service, (2016, October 7). KMC starts generating gas from waste. The Himalayan Times. Retrieved from https://thehimalayantimes.com/kathmandu/kmc-starts-generating-gas-waste/

Martin, R. (2012). Global Waste-to-Energy Market to Reach $29.2 Billion by 2022, Forecasts Pike Research. Retrieved from http://www.businesswire.com/news/home/20120323005151/en/Global-Waste-to-Energy-Market-Reach-29.2-Billion-2022

Nelles, M., Dorn, T., Wu, K., & Cai, J. (2011). STATUS AND PERSPECTIVES OF WASTE INCINERATION IN CHINA Paper presented at the International Conference on Solid Waste 2011-Moving Towards Sustainable Resource Management, Hong Kong SAR, P.R. China.

Pinak, R., & Geeta, B. (2011). Estimation of Power Generation from Solid Waste Generated in Sub Urban Area using Spatial Techniques: A Case Study for Pune City, India. INTERNATIONAL JOURNAL OF GEOMATICS AND GEOSCIENCES, 2(1), 179-187.

Shah, D. (2011). The Timarpur-Okhla Waste to Energy Venture. Retrieved from http://www.no-burn.org/downloads/Timarpur.pdf

TANDAN, P. K. (2016, August 20). Waste-to-Energy machines arrive in Birgunj. The Himalayan Times. Retrieved from https://thehimalayantimes.com/nepal/waste-energy-machines-arrive-birgunj/

Waste-to-Energy Research and Technology council (WTERT), (2016, October 7). The ABC of Sustaibale Waste Management (SWM). Retrieved from http://www.seas.columbia.edu/earth/wtert/faq.html

DESIGN, MODIFICATION, FABRICATION AND IMPLEMENTATION OF MECHANICAL MULTI-HAND MOLD BRIQUETTE KEY

Ashok Acharya[1], Prasil Raj Shrestha[2] Nashla Shakya[3] Manoj Shrestha[4] Sudarshan Poudel[5]
[1]Lecturer at Department of Mechanical Engineering under Design and Manufacturing Subgroup, Kathmandu University, Dhulikhel, Kavre, Nepal
[2, 3, 4 & 5] First year students of Bachelor of Mechanical Engineering at Kathmandu University, Dhulikhel, Kavre, Nepal

'Kathmandu University Community Education Project' (KU CEP) is a program run by Kathmandu University that intends to work in collaboration with national and international organizations and agencies for improving the quality of life of rural people through Community Education Programs.

The project entitled "Design, Modification, Fabrication and Implementation of Mechanical Multi-Hand Mold Briquette Key" was conducted at Workshop of Department of Mechanical Engineering with the financial assistance from KU CEP. The Mechanical Multi-Hand Mold Briquette Key is a machine based on the principle of conservation of energy. When the raw material (Charcoal powder is mixed with bentonite clay at a ratio of 3:1 with addition of water) is poured manually into the system which further compressed manually in multi-hand mould die gives an output of three briquettes of diameter of 130 millimeters and the height and further it needs sun-dried. The process from loading the biomass to extrusions from die is manual.

The design of the Multi Hand Mold Briquette Key as shown in figure 1 includes three cylindrical male dies having rods protruding towards the cylinder which is fixed in a table having three base plates for the ejection of briquettes which is connected to the hydraulic jack which helps to extrude the briquettes. Female dies are attached to the screw which drives the female dies towards the male die and compresses the biomass paste to form compact, compressed briquettes. Female dies are simply base plate having holes on it.

Figure 1: Multi Hand Mold Briquette Key

First the paste is added to the male die and the screw is rotated so the female die moves downward towards the male die and the paste is then compressed. Then the screw is rotated in opposite direction and the briquette is then ejected with the help of hydraulic jack placed below the table.

Molding is a two press process. But firstly, the pastes for the briquette are to be prepared. For the paste, firstly green plants are collected from the nearby locality and are kept at a place for drying. After the moisture is removed from the green waste, the plants are then mechanically fragmented by using crushing machine or manually by hands. Then the dried materials are burnt in a charring drum or in a pit and little by little materials are added but the raw materials are not completely burnt. The process of semi burning the biomass is done layered by layered. Once the fire is extinguished and cooled down, the coal is taken out, pounded into powder, mixed with the binding sticky clay soil with water all in appropriate ratio (3 parts of coal: 1 part of binding clay soil). The well-mixed coal is put in the male die. Through screw mechanism pressure is applied to the mixture due to which the mixture reduces to half of the initial mixture. Again the biomass is added to the male die and the process is repeated again. Finally, the briquette is ejected with the help of hydraulic press. The briquette is then taken out and dried for 2-3 days under the sun. While drying, briquettes should be kept on plane and hard surface and should be covered with plastic during the night to protect from rain and wind. Once the briquette is dried and made hard, it is ready for burning in the briquette stove. When produced manually, one person can make about 30 round beehive briquettes with 16 holes through which blue fire-flame comes out when burnt. Depending on the quality of briquettes, one beehive briquette burns for an hour to two and half hour. If the semi-burnt charcoal is machine pressed, it results better fire efficiency. Cost of the briquette piece ranges from NPR 30-40. A normal meal for a nucleus family of 4-5 members can be cooked with one briquette.

Manually Pressed Beehive Briquette Press as shown in figure 2 is the most commonly used and the simplest briquette press available in Nepal. It is also the most time consuming process for making a briquettes and consist of a female die and a male die with a handle attached on a female die. Male die consist of a cylindrical shape with a base plate having rods protruding outside where the briquetting paste are added. While female dies are the base plates with holes in it with a handle which is used to press the biomass paste. Since, the briquettes are pressed manually by hands, so there is a chance of unequal pressure distribution due to which the briquettes may not be compactly packed and may result in cracking of briquettes.

Figure 2: Manually Pressed Beehive Briquette Press

DEVELOPMENT OF MULTI HAND MOLD BRIQUETTE KEY:

Traditional Beehive Briquette Press accounts to problems in making the briquettes. So we decided to build a press that can account to most of the problems faced by it. Multi Hand Mold Briquette Key as shown in figure 3 accounts to those problems as it is screw driven than manually pressed and can make multiple briquettes at a time which makes it more efficient than the manually pressed briquette key. Since, it is screw driven, the pressure is equally distributed, and so fewer cracks are seen in bio briquettes.

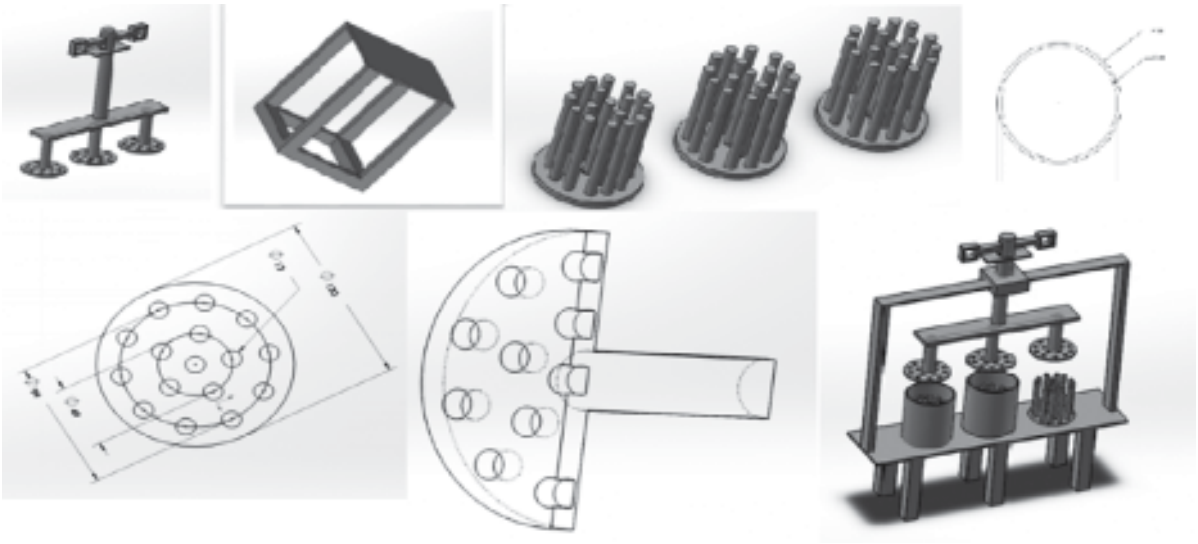


Figure 3: Modeling design of Multi Hand Mold Briquette Key

TECH DESCRIPTION:

For the completion of the project, we seek help from both internal and external professors, and experts from related organizations. We use two types of drafting software for the designation of the concept module of Multi Hand Mold Briquette Key. They are:

Solid Works 2015 Edition (For Modeling)
AutoCAD 2013 Edition (For Manufactures drawing)

As an external supervisor and expert of biomass and energy Dr. Ramesh Man Singh of Centre for Energy and Environment Nepal (CEEN) provided some important suggestions regarding the development of mechanical Multi-Hand Mold Briquette Key.

IMPLEMENTATION PHASE:

After the completion of the project, it was then implemented to the community based entrepreneurs at Dolakha District with the motive to uplift the existing enterprise. The team from KU CEP demonstrated working mechanism to the community.

Figure 4: During the demonstration of working mechanisms of Mechanical Multi-Hand Mold Briquette Key

Figure 5: Mechanical Multi-Hand Mold Briquette Key (Aerial view)

REFERENCES:

Acharya Ashok and Ripsu Maharjan, 2010, "Appropriate Technology Directory", NEDC, December, pp. 13-17.

Ramesh Man Singh and Mridaney Sharma Poudel,2013 "Briquette Fuel - An Option for Management of Mikania micrantha" Nepal Journal of Science and Technology Vol. 14, No. 1 (2013) 109-114

Kathmandu University, Community Education Project (CEP), Dhulikhel, Kavre.

RENEWABLE ENERGY OPTIONS IN COMBATING CLIMATIC CHANGE EFFECTS

Prem Bikram Karki
Rural Enterprise Development Officer, PEEDA

Pollution, one of the major indicators of climatic change is increasing rapidly at a higher rate. The emission of green house gases has started to cause environmental hazards like increase in global temperature, rise in sea level and ozone layer depletion. It has been stated recently by media, the highest temperature till date was recorded in June 2016 whereby the first 8 months of 2016 has shown temperatures increase above average than in the previous years. The global average surface temperature is forecasted to increase by 1.4 to 5.8 degrees by 2100 AD in relative to 1900 AD. Similarly, the globally averaged sea level is projected to rise from 0.09 m to 0.88 m by 2100 AD. Such results would disturb the natural global cycle phenomenon whereby the role of renewable energy could balance and combat climatic changes to some extent.

Rural energy deprivation has been one of the major reasons for the increase in vulnerability due to climate change. The electricity generation accounts for greater than 30% till date. 5-8 years back, the global average consumption was 60 GJ/capita with the range from Sub-Saharan South African countries consuming only 0.6 GJ/capita while North Americans consuming 300 GJ/capita. With low access to modern energy services, biomass accounts for around 90% of the energy supply in rural parts of developing countries. Incorporation of aggressive environmental and energy taxes for simultaneous environmental protection namely "Ecologically Driven" relying on local resources, decentralization of energy systems and focus on productive end use options might stabilize atmospheric CO_2 concentrations to an acceptable level. De-carbonizing global energy systems would then resolve rural energy deprivation to some level.

The effect of climate change has resulted in disparity among developed and developing as well as least developed countries thereby making it difficult for the people of the latter countries to adapt to climatic changes and thus showing in a lower degree of sustainable development in such least developed and developing countries. Poverty alleviation through sustainable development could be reached via use of bio-energy that provides green house gas mitigation levels, fulfills basic rural livelihoods and transformation into electricity generation. Basic energy needs at rural levels are met at high human energy costs mainly borne by women and children. The advantages of decentralized renewable energy systems are large and not limited to biodiversity and ecosystems management, access to safe drinking water and sanitation services, bio-energy usage for lightning and cooking, mitigation of natural disasters and climate variability and change. Land and water resource management and livelihood options can be achieved via decentralized renewable energy options in the form of pumping water, post harvest processing, better lightning and cooking options, reduction in exposure to indoor pollutants and better health and safety. The relation between bio-energy and ecosystems can be improved thereby resulting in increase in agricultural productivity, soil and water conservation, food security, and well being of living beings.

The growing climate change effects have started showing threats that affect the human race. In such situations, the role of the energy services should be stated by the government looking in view the energy systems contribution to poverty alleviation and sustainable development. Encouragement for capacity building efforts in relation with renewable energy should be undertaken quickly. In overall, a proper coordination among all the concerned stakeholders needs to be mechanized properly and action should be undertaken promptly to combat climatic changes and bring in about sustainable development via renewable energy options. There is a good range of renewable energy technologies available currently and that developed countries still work on advancing such technologies and cutting down costs. The emission of green house gases comes down to zero by the use of such technologies thereby having minimum environmental impact. Furthermore, such renewable energy sources do not get depleted

and can be used for long run. As such, a proper appropriate energy conversion technologies need to be updated and brought into effect soon. Green jobs and economies can be created leaving behind low carbon footprints in the global market. Thus, government needs to bring into light the measures of reduction in carbon and green house emission via the renewable energy options and encourage local people to adopt such options at the local level.

REFERENCES:

Dincer, I. (1999). Renewable Energy and Sustainable Development: A crucial review.

Venema, H. D. (2007). Decentralized renewable energy and the climate change mitigation-adaptation nexus.

DECENTRALIZED RURAL ELECTRIFICATION – A MYTH OR A REALITY?

Bhawesh B. Singh
M.Sc., B.Sc. - Energy Systems, Electrical Engineering
Aachen University of Applied Sciences, Germany
Presently: Planning Engineer, Heat Pumps & Solar Thermal Systems
Stiebel Eltron GmbH & Co. KG, Holzminden, Germany

Despite having one of the lowest per capita energy demands in the world and high hydro power potential in this planet, only 50% of the population in Nepal enjoys grid power supply, with the caveat of up to 18 hours of load shedding a day during the dry months of the year. 20% of the population receives their electricity with individual ad hoc solutions like Solar Home Systems (SHS), small wind turbines and pico-hydro plants which are often insufficient to make productive use of electricity. The rest 30% are still to see lights of electricity. Considering the geographical remoteness, a scattered and low density consumer profile, higher costs of supply of maintenance, it is difficult and implausible to extend the national grid to every village in Nepal. Consequently, the only solution to provide the entire population with energy will be to decentralize the energy production and supply. This techno-economic paper examines the economic viability of off-grid renewable energy mix technologies, comprising of micro hydro, solar and wind, to provide sustainable energy with for productive end use in the households of Mahadevsthan in Dhading, Nepal. The energy consumption of existing households along with other vital components, like small-scale business, schools, clinic, telecommunication tower etc, for a self-sustaining, socially developing and economically growing model village is simulated using HOMER.

The coherent relationship between electricity and socio-economic development has been analyzed; social-benefits in terms of Social Return on Investment (SROI) has been calculated in US-dollars by estimating impacts on education, health, entertainment, productivity and environment to make the project more attractive. The study aims to technically and economically evaluate the Mahadevsthan Rural Electrification Project (MREP) to provide people of Mahadevsthan, Dhading with 523 kWh each day and compare the energy prices they would have to pay to the electricity price from the national grid provided by Nepal Electricity Authority (NEA). The analysis has indicated that the levelized cost of off-grid renewable energy is cost-competitive with NEA provided the villages are further than 20 km from existing national grid and the government subsidizes 50% on initial investment costs. Finally, a business plan is provided to encourage micro-entrepreneurship and demonstrate that rural electrification is feasible especially with favorable subsidies and tax incentives by the government.

After visiting the project village, Mahadevsthan in Dhading, it was confirmed that micro hydro would be the integral part of the hybrid system. The measurement of the head and the water flow resulted in the possible power production of 26.8kW from the micro hydro plant. The energy consumption of 175 households, small-scale industries, clinic, school, local offices, BTS amounted to 58kW peak installation with a daily demand of 523kWh. The difference was supplemented by 4 units of 1.5kW enbreeze wind turbine and 7kW solar PV. Solar, wind and hydro energy are complimentary in nature. In rainy season when solar and wind energy are deficient, hydro provides maximum power. Contrarily, dry seasons in Nepal are characterized by relatively more solar irradiation and wind. By integrating and optimizing the PV, wind and hydro power systems with suitable sized battery arrays as storage, a cheaper and more reliable system with minimized unit costs can be achieved as shown in the simulations. It is also economically and system-wise advantageous when households are electrified as a part of the community rather than a single household at a time. Community electrification facilitates "electricity sharing" since in the real world the electricity consumption pattern of all the households are not exactly the same, although it has been attempted to emulate the load pattern in the simulations by adding disturbances to hourly and daily loads.

The average price of electricity for general consumers in Nepal in the fiscal year (FY) 2012 was NPR 7/kWh (0.081 US$) (Source: Nepal Electricity Authority, NEA). From the simulations the lowest electricity price with the PV-Wind-Hydro hybrid was found to be $0.118 and $0.109 with 10% capacity reduction. With hundreds of perennial rivers emerging from the Himalayas and the steep gradient of country's topography, Nepal enjoys the ideal conditions for the development of both large and small hydropower plants. The results from assignment and thesis deduce that the best energy supply for Nepal's remote area is the hybrid with micro hydro. The price of energy is as competitive as the energy prices from the NEA. Additionally if the cost of the new grid extension is added to the cost of electricity from large hydro power stations, the decentralized hybrid solution might prove to be less cost intensive. The cost in developing countries of a single-wire grid extension was evaluated at 9000 US$/km (Nfah et al.). The annual operation and maintenance costs amount to 180 US$/yr/km while the grid power price is set to the local grid price of 0.144 US$/kWh.

Although the purchasing power of the people from bigger cities are distinctly higher than their counterparts in the villages, there have been projects around the world run by local rural companies that have provided electricity at affordable rates to the rural people. More importantly, Ellegard et al., 2004, have mentioned that those local companies can sustain their operation through the fees paid by the customers. People also are willing to pay more for the renewable energy than what they used to pay for kerosene, firewood and dry cells.

REFERENCES:

Nfah E. M. et AI. "Simulation of off-grid generation options for remote villages in Cameroon" Renewable Energy 33, Elsevier; 2008, pp. 1064-1072.

Ellegard A., Arvidson A.,Nordstroma M.,Oscar S. Kalumiana , Clotilda Mwanza : Rural people pay for solar: experiences from the Zambia PV-ESCO project

ZERO ENERGY SOLUTION FOR COLD STORAGE IS AMAZING. WANNA TRY?

Prakash Acharya
Founder, Mukti Energy
E-mail: contact@muktienergy.com

I don't have a refrigerator at my flat, so I came across a problem of fruits and vegetables deterioration sooner during summer. I couldn't buy more fruits to store for more days. The vegetables like tomatoes deteriorated and flies were attracted to it which made my kitchen so unhygienic. So, I thought of a simply proven technology at my home which might help to keep vegetables and fruits fresh for days.

This was not the first time I was making it. I loved this technology at my school project too. My intense interest in zero energy technology drove me again to learn more about it, build, test and analyze the performance. So, here's what I want to summarize the "zero energy cold storage" technology.

"ZERO ENERGY COLD STORAGE TECHNOLOGY"

Zero energy cold storage works on passive cooling principle which means no use of any forced pump or compressor for cooling. It is totally a natural process where system is designed such that the system maintains the temperature below ambient temperature without use of any kind of energy, particularly fossil fuels. This technology can be a boon to store agricultural products cool and fresh in rural areas which has no access to grid energy. It helps enterprise being sustainable by increasing longevity life where as decreasing damage of agro products till the access of market. It also helps to maintain nutritive value of fruits and vegetables good.

Zero energy cold storage can be built with "Evaporative Cooling" principle. It can be classified in two types

1. Pot in Pot Refrigeration for household utility
2. Community cold Store

EVAPORATIVE COOLING

The science behind evaporative cooling system is "During evaporation it gains heat energy from the system so the temperature of system goes down "Or simply to understand "Evaporation causes cooling".

For example from our day to day life, water in a clay pot is cooler than the water in the plastic bucket because clay pot has small pores and water evaporates with the air flow through that pores. The same principle can be applied to build a "Pot in Pot Refrigerator" or a "Community Cold Store". The rate of cooling depends on rate of airflow in outer surface of refrigeration.

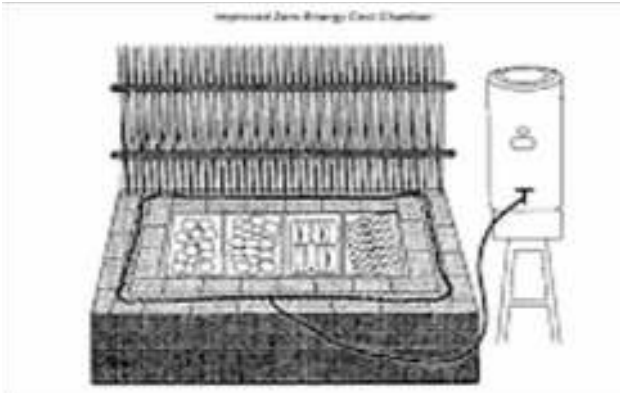
Evaporative cooling is effective to keep agro products at 8 ^{0}C to 12 ^{0}C , which means relative rate of deterioration of products are maintained at 3 and potential shelf life is 15 to 20 days i.e. gaining 5 times longer life.

Pot in Pot Refrigeration

It is a simple technology which can be built in a local level with the use of two clay pot, one inside another where fine sand is filled in between two pots. The fresh fruits and vegetables are kept inside the inner pot and the water is sprinkled on sand timely to cause evaporation.

This technology is useful in small scale where load is between 6 to 10 Kgs.

Community Cold store



Community zero energy cold store can be build with two brick walls, with the gap of 10 – 12 centimeter in between the walls which can be filled with the fine sand. The size of room can be designed on basis of volume of load. The fresh fruits and vegetables are kept inside the store in a porous crate. Here, water is drenched or sprinkle timely in the outer surface of the wall and in between the walls.

CONSTRUCTION

- Lay the floor of cold storage cabinet with the bricks.
- Erect the brick walls with the gap of 10 to 12 cm in between the walls.
- Sprinkle the cabinet with the water.
- Fill the gap between the walls with the fine sand.
- Drench the sand portion and outer surface of wall with the water. The water should be drenched in sand and outer surface of wall twice a day.
- Store the agro products in plastic crate with enough air flowing pores/ holes.
- Cover the cabinet with well insulated roof or lid.

IMPROVEMENTS IN EVAPORATIVE COOLING SYSTEM

Use of solar powered fan, preferably computer processor fan (in Pot in Pot refrigeration) and 6 inch dc fan (in community cold store) in outer surface of four walls can help increase the air flow so that to speed up the evaporation rate. Higher the evaporative rate higher the cooling rate.

PEEDA AT A GLANCE

PEEDA is an NGO dedicated to improve livelihoods of communities, particularly the poor, by collective utilization of renewable energy resources, while ensuring due care for the environment. This is achieved by establishing institutions active in the renewable energy sector, promoting cooperation between relevant stakeholders to undertake development projects, advocating for policy and regulatory reforms and undertaking targeted research. The principle behind the activities of PEEDA is that the poor of Nepal, who live mainly in rural areas, should share in the benefits of Nepal's renewable energy resources, but this will not happen without dedicated and sustained effort. PEEDA is committed to the values of empowering individuals and communities to help themselves, non-discrimination, and maintaining good relationships.

NEWS & EVENTS

1. A BRAINSTORMING WORKSHOP FOR PEEDA'S STRATEGIC PLANNING

At this juncture of time, PEEDA board realized that PEEDA needs to have a strategic focus on some direction so that the projects can be developed and implemented more effectively in an efficient manner. This will also give a direction to the board/staffs on how to go forward. In this context, PEEDA board had planned to organize a meeting of its general members and its staff to discuss and derive the future course of PEEDA. Hence, about 30 individuals comprising of general members, staffs and few invitees of PEEDA participated in the half day brainstorming workshop organized in Besisahar of Lamjung district on 9th April 2016. The overall objective of this gathering was to finalize PEEDA's course of action for the coming future.

2. APPOINTMENT OF NEW CEO

On 8th of July 2016, Mr. Biraj Gautam has been appointed as Chief Executive Officer of PEEDA.

3. RECRUITMENT OF SOCIAL MOBILIZERS

PEEDA has recruited four social mobilizer for the project namely "Climate Resilient Communities and Sustainable Livelihood Initiatives for Pro-Poor of Dolakha District of Nepal". Furthermore, PEEDA has successfully completed orientation and training program for the social mobilizers from 20th to 24th September 2016.

PEEDA

Published by:

People, Energy & Environment Development Association (PEEDA)
Devkota Marg, Mid-Baneshwor, Kathmandu-10
GPO Box 8975, EPC 2157
Tel: +977-1-4469456/458
Website: www.peeda.net

For feedback and suggestions, please write to: mail@peeda.net