Volume V - 2018

# ENERGY INSIGHT

## Yearly Publication of PEEDA

PEEDA

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# MESSAGE FROM THE CHAIRPERSON

The role of non-government organizations is indispensable 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 three institutions e.g. -Hydro Lab P. Ltd. established for hydraulic modeling, Hydro Consult Eng. Ltd.established for providing quality engineering consultancy services and Center for Energy and Environment Development. 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,

**Murali Prasad Sharma**

**Chairperson, PEEDA**

# MESSAGE FROM THE CHIEF EXECUTIVE OFFICER

Access to energy for all is universal right. However, about 24% of Nepalese are still without electricity. There are plenty of resources that can be utilized to provide energy access. It is proven that decentralized energy generation systems are a quick and effective way of addressing energy access for rural Nepal. In this context, Nepal's energy system needs to be sustainably based on a diverse mix of energy sources, addressing the pressing challenges of security of supply and climate change.

PEEDA has been conducting various energy and environment related activities and projects over the last 20 years. PEEDA has been exploring and executing concepts and technologies that could impact lives in the short and long term. PEEDA is currently executing five 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 concerning renewable energy and the 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 the successful publication of "Energy Insight" last year, this is the fifth version to be delivered to the concerned stakeholders. However, I do acknowledge that there might be plenty of shortcomings with regards to the content and the concepts expressed here. I sincerely hope that your valuable comments, suggestions and advice can 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 thanks to the Chairperson, the Executive Committee, my colleagues, partners - specifically Bread for the World (BfdW) and WISIONS for their support in publishing this Annual Magazine.

Thank you,

**Biraj Gautam**

**Chief Executive Officer, PEEDA**

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# Leveraging renewable energy for local economic development in Nepal

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## Background

Globally, the Sustainable Development Goals (SDGs) were adopted by the UN General Assembly in 2015 with a principle of 'leaving no one behind' and an emphasis on 'a holistic approach to achieving sustainable development for all'. The SDGs has 17 goals, among which 'affordable and clean energy' is the 7th Goal. SDG 7 has the goal to 'ensure access to affordable, reliable, sustainable and modern energy for all' with various targets to be achieved by 2030, such as increasing the share of renewable energy in the global energy mix, double the rate of improvement in energy efficiency, improving infrastructure and upgrading technology, in particular for LDCs. Recognizing the importance of local governments, communities and actors in successfully implementing the grand vision of SDGs, a lot of focus has been given to localizing SDGs.

In Nepal, the new long-term development agenda of Nepal is derived from the national objective of reaching the middle-income status by 2030 by closing the gender, social and geographical gaps and moving towards shared prosperity. Fortunately, Nepal's goals in its new socio-economic era coincides with the ambition of the global community to implement and achieve the SDGs by 2030. The global ambitions are broadly aligned with the social, economic and environmental aspirations that Nepal has set for itself in its Constitution. Nepal's Constitution embraces the principles of democracy, federalism and inclusiveness. It has provisions of three levels of government: federal, provincial and local. Accordingly, there are seven provinces and 753 local levels. Governments have been formed at all three tiers after the successful completion of elections in 2017. The newly elected governments at all levels face the challenge of defining prosperity and addressing the high aspirations of the people.

In this context, the purpose of this article is to present some brief ideas on how renewable energy can be leveraged for local economic development (LED) in Nepal. The article will define the concepts of LED, renewable energy development in Nepal, link the two concepts, and conclude with some policy recommendations.

## Local Economic Development (LED)

Scholars have put forward various reasons for LED's relevance but broadly agree on the characteristics that underpin a good LED process. LED practice has grown in relevance in the recent decades due to failure of top-down national approaches in the face of globalization (Rodriguez-Pose, A. & Palavicini-Corona, E. I., 2013), technological change (Potter et al., 1999), arguments by economic thinkers for government intervention to cure the ills of privatization and liberalization (Rodrik, D., 2004), and new ways to think about innovation policy where governments pursue 'opportunity-driven investments' not only to correct market failures but also create 'market landscapes' (Mazzucato, M., 2016, p. 140). The multitude of reasons for relevance mean LED is a mix of various approaches and there is no unique definition of a good LED process. Nevertheless, good LED processes bear some defining characteristics. Rodriguez-Pose and Palavicini-Corona (2013, pp.304-305) identify seven key features of LED: 'development plan', 'sustainability', 'local leadership and entrepreneurship', 'capacity building', 'participation mechanisms', 'development links among agents', and 'political autonomy'. Other scholars have also focused on the ‘local participation and partnerships’ and ‘inclusive growth’ dimension of LED. Institutions like the ILO have put focus on inclusive growth agenda of decent jobs as part of LED (Canzanelli, G., 2001) while others such as UN-Habitat focus on its strategic elements. Still others have focused on aspects such as governance, learning, and sustainability.

## Renewable Energy in Nepal

The Government of Nepal has put a strong emphasis on energy development, especially by ensuring access to clean and renewable energy to all. Nepal has been relatively successful in solving the energy crisis recently. The Government aims to build on this success and sustainably utilize its rich energy potential. The Government is focusing its efforts on developing and expanding hydroelectricity and all types of renewable energy to provide clean energy to all households within the next three years and avail smooth electricity supply across Nepal within the next five years. Accordingly, the Government has set forward a target to increase per capita electricity consumption up to 1500-kilowatt hour (kWh) within the next 10 years by transforming consumption and distribution pattern so as to minimize the need for fossil fuels. To achieve these ambitions, it plans to produce 3000 megawatt (MW), 5000 MW and 15000 MW hydroelectricity within the next 3, 5 and 10 years, respectively, out of the economically feasible 43,130 MW, through public and private investment in small, medium and large hydroelectricity projects. These ambitions are also reflected in the white paper launched in May 2018 by the Ministry of Energy, Water Resources and Irrigation. The white paper also incorporates ‘One Province, One Mega Project’ strategy with an aim to build a mega hydro or solar project in each of the seven provinces. In addition, the Transmission System Master Plan (TSMP) unveiled in July 2018 aims to develop 6,867 kilometres of transmission line across Nepal.

Nepal has already showcased a successful model of energy development through the involvement of the private sector. Nepal’s private sector has played and continues playing a vital role in hydropower development as it makes up nearly half of the total installed capacity of 1073 MW. Moreover, while 2200 MW of hydropower projects are under construction, 1300 MW of hydropower projects have undergone power purchase agreement which are awaiting financial closure. More than three thousand micro-hydropower plant (MHPs) have been installed so far in remote areas. The MHPs are owned and managed by communities and ensure a reliable alternative source of energy by providing off-grid access to a significant population. Similarly, solar energy is slowly being developed in Nepal. The recent approval of Dolma Impact Fund’s investment worth 200 million USD in solar energy of size 170 MW by the Investment Board Nepal.

## Linking Renewable Energy to Local Economic Development

Various studies have examined the impact of renewable energy on LED. Liu (2016) examines the impact of both the production and consumption of renewable energy on LED and income using panel data from 31 Chinese provinces for the period from 2000 to 2010. The study found that there was significant positive impact from renewable energy provided that there were right subsidy policies (Liu, W., 2016). It might be tempting for local governments to subsidize the development of renewable energy. However, it must be ensured that the incentives are scientific and maximise the benefits. Similarly, a study with cases study of an Indian state also has found out that renewable energy systems are much better than conventional energy systems is addressing economic problems (7). Another study that analyses the impact of renewable energy on the economy of Lithuania concludes that the development of renewable energy has positive impact on the economy in terms of reduction in fuel imports and creating of new jobs (8).

According to the OECD (OECD, 2012), ‘renewable energy is being championed as a potentially new source of jobs and rural growth’ and ‘a means of addressing environmental and energy security concerns’ (OECD, 2012). The report points out that renewable energy has benefits such as generation of 'local revenue, local jobs, innovations in products, processes and policies, capacity building and local empowerment', among others. Currently local governments in Nepal are struggling to identify new avenues for generating resources to support the development of their territory. In this context, renewable energy can help generate revenues. Similarly, whereas in the past, renewable energy such as biomass energy used to be labour-intensive, renewable energy such as solar are more capital intensive. This limits the potential to create many local jobs. However, this can be overcome by linking renewable energy development with industrial production of relevant infrastructure. The Constitution has given power to the local and provincial governments in a wide range of areas and they are well positioned to leverage this opportunity.

## Conclusion and policy recommendations

To conclude, this essay presented both the concepts of local economic development and renewable energy. With the need for achieving SDGs by 2030 as a backdrop, it analysed the relevance of leveraging the development of renewable energy to achieve SDGs. It further took the recent change in governance structure of Nepal and discussed how renewable energy could be leveraged for local economic development in Nepal to ensure that prosperity is defined and carried out by the provincial and local governments. The findings suggest that renewable energy can be an important driver of local economic development, but it is not a panacea for development aspirations. The findings have important policy implications. Firstly, governments at all levels should focus on the development of renewable energy that are affordable as the price of energy is a factor that dictates its adoption especially in areas with relatively large population of low-income people. Secondly, governments need to focus on renewable energy that have the greatest potential to create jobs as only by linking jobs with development will they be able to ensure inclusive growth. Thirdly, instead of blindly copying renewable energy development strategies, provincial and local governments in Nepal should learn from successful cases and only plan and carry out strategies that are technically, financially, environmentally, and socio-economically feasible for themselves.

## References

Canzanelli, G., 2001. Overview and learned leassons on Local Economic Development, Human Development, and Decent Work. [Online]
Available at: http://hdrnet.org/241/1/Canzanelli_Overview_LED.pdf
[Accessed 5 October 2018].

Liu, W., 2016. Is renewable energy effective in promoting local economic development? The case of China. Journal of Renewable and Sustainable Energy, Volume 8.

Mazzucato, M., 2016. From market fixing to market-creating: a new framework for innovation policy. Industry and Innovation, 23(2), pp. 140-156.

OECD, 2012. Linking Renewable Energy to Rural Development, Paris: OECD.

Potter, J., Walsh, J., De Varine, H. & Barreiro, F., 1999. Best Practices in Local Development, Paris: Local Employment and Economic Development Programme, OECD-TDS.

Rodriguez-Pose, A. &Palavicini-Corona, E. I., 2013. Does local economic development really work? Assessing LED accross Mexican municipalities. Geoforum, Volume 44, pp. 303-315.

Rodrik, D., 2004. Industrial Policy for the Twenty-First Century. [Online]
Available at: https://myweb.rollins.edu/tlairson/pek/rodrikindpolicy.pdf
[Accessed 4 October 2018].

# Role of women to adopt modern electric cooking in Nepal

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## Introduction

Access to clean cooking energy is a problem in Nepal especially for women because they are usually responsible for cooking (SARI 2018). Cooking with liquefied petroleum gas (LPG) or electricity is urban cities is taken for granted, but for many people living in rural Nepal, traditional wood burning is still the only option. Even though access to improved energy has been an important and demanding component of development, recently the Government and its associated bodies have brought new emphasis to this issue.

According to the Annual Household Survey Report 2014/15 published by Central Bureau of Statistics, traditional wood fuel is a major source of cooking fuel in Nepal, serving more than 60% of total households (GoN, 2016). Cooking energy makes up a substantial portion of Nepal's energy demand. Everyday cooking in the home kitchen is still women's work. The smoke released from burning wood fuel contains a range of health damaging pollutants such as small particles and carbon monoxide which can lead to respiratory infections, chronic obstructive pulmonary disease and even lung cancer. In additional, household wood fuel smoke is a risk factor for low birth weight, asthma, tuberculosis and adverse pregnancy outcomes (Cecelski & Matinga, 2014).

## Linking modern cooking fuels with women

In rural parts of Nepal where access to modern energy sources are lacking, women are primarily responsible for collecting biomass fuel for cooking purposes and sometimes they are vulnerable to violence while traveling to the forest after sunset to collect biomass fuels. Moreover, women spend the most time preparing meals and must take care of children at the same time. Such tasks are considered unpaid work, despite being essential to the survival of family members. Thus, in most rural areas, time spent by women to collect wood can range from one to five hours per household per day (ENERGIA, 2006).

Improving women's time constraints through better infrastructure and technology is one of the priorities to improve gender equality. Modern cooking stoves and fuels (LPG & electric cooking) can save women's time and greatly reduce health risks. A recent project conducted by People, Energy and Environment Development Association (PEEDA) in collaboration with University of Bristol assessed the potential for low power electric cooking and found that despite constraints such as fear of electric accident, higher electricity price or irregular power supply, women often choose electric cooking when they have the option. This low power electric cooking assessment project demonstrated their feasibility for use even in off-grid areas of Nepal, with minor setting modifications. The results show considerable reduction of women's workload.

*Figure 1: Traditional wood stove (Photo: Author)*

*Figure 2: Electric induction cooker (Photo: Author)*

Access to modern clean energy for cooking is as crucial as the proper ingredients necessary for food preparation. Time saving and reduction of work load due to modern fuel switching can enable women to take advantage of development and empowerment opportunities to improve their and their families lives through income generating activities. Moreover, modern fuel switching can prevent people from health damaging pollutants such as carbon monoxide.

Fuel switching from traditional biomass to clean energy such as hydropower is essential for the sustainable future of Nepal. Hydroelectricity is a cleaner source of cooking fuel and it does not cause continuous deforestation or environment pollution. Such clean and affordable cooking energy access is an important social goal to pursue. Over the past few years, the government has made efforts to increase the distribution of clean cooking energy solutions like improved cookstoves (ICS), and biogas plants. Some of the milestone policies and programs undertaken by Nepal government are summarized below.

*Table 1. Summary of Nepal government policies and programs*

| Fuel or Technology | Government Policies and Programs |
|---|---|
| Improved Cooking Stoves | • ICS was introduced in 1950s and continues to be relevant in the present context.<br>• AEPC/NRREP together with other government, non-government and private organizations are involved in developing and promoting different types of ICS in Nepal<br>• More than 700,000 improved cook stoves have been installed in 63 districts |
| Rural Energy Policy -2006 | • Its objective is to reduce energy poverty and encourage environment conservation in rural areas.<br>• Preparation of an action plan for the promotion and use of biogas, firewood, briquette, biomass, improved cooking stoves. |
| Rural Energy Subsidy Policy | • Provision of subsidies for the promotion of biomass energy technologies such as biogas, improved cook stoves, gasifier etc.<br>• To reduce dependence on traditional and imported energy by increasing access to renewable energy for improving the livelihoods of people and create employment opportunities especially in the rural areas. |
| Biomass Energy Strategy | • One of the main objectives of this policy is to contribute energy supply and energy security by generating energy through management of agriculture forest residues and organic wastes from municipal urban and industrial areas. |

## Empowering women on clean energy cooking

Educating women about the costs and benefits of different clean energy cooking fuels is a key way to promote modern technology and improve the health of the family. In all Nepalese cultures, women usually manage household energy, thus women play a vital role in the spread of new technology adoption and the use of clean residential cooking solutions (GACC, 2018). Therefore, their active participation is vital for a more sustainable future. To conclude, women and girls play an important role in spreading awareness about the dangers of indoor air pollution and introducing new technologies to mitigate them.

## References


Cecelski, E., & Matinga, M. (2014). Cooking with Gas: Why women in developing countries want LPG and how they can get it. World LP Gas Association. https://www. esmap. org/sites/default/files/resources-document/WLPGA.

ENERGIA. (2006). From the Millennium Development Goals Towards A Gender-Sensitive Energy Policy Research and Practice: Empirical Evidence and Case Studies Netherland: Secretariat ENERGIA International Network on Gender and Sustainable Energy,.

SARI. 2018. Nepal: South Asia Regional Initiative for Energy Integration. Accessed November 2018. https://sari-energy.org/oldsite/PageFiles/Countries/Nepal_Energy_detail.html.

GACC. (2018). Clean Cookstoves Can Save Lives & Empower Women. from Global Alliance For Clean Cookstoves Available on https://cleancookstoves.org/binary-data/RESOURCE/file/000/000/278-1.pdf

GoN. (2016). Annual Households Survey 2014/15. Kathmandu: Government of Nepal -Central Bureau of Statistics.

# Nepal – Still the Pioneer of Micro Hydro in S/SE Asia

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Micro hydropower (MHP) development in Nepal over the last 30 years has inspired the sector's development across south and southeast (S/SE) Asia. From transitioning watermills to pico hydro, to the development of the T-12 crossflow turbine, impactful productive end use, and projects financed by banks, Nepal has been the home of the earliest technical and institutional progress advancing MHP.

Recent years in fact reflect the same – Nepal continues to pave the path in developing expertise to address present-day MHP challenges, being able to leverage on its decades of hindsight. Let's take a closer look!

*Figure 1: Micro-hydropower located at Simle, Rukum district*

## Interconnection of MHP to the Central Grid

As the central grid in all countries expands, many MHP communities across S/SE Asia face a dilemma: *what happens to the MHP project after the grid arrives?* In cases where electricity from the central grid is reliable, grant-funded community-owned projects have been abandoned and self-financed projects are at risk of losing investment. To resolve this, in 2017 Nepal became the third country in the region to interconnect existing community MHP to the central grid. Nepal's effort is unique because it was led by government and the utility, namely the Alternate Energy Promotion Centre (AEPC) and the Nepal Electricity Authority (NEA). In finalizing a national policy for MHP interconnection, decision makers took time to study the progress in Indonesia and Sri Lanka. They also keenly requested the services of local, long-experienced private sector pioneers, such as Mr. Surendra Mathema and other members of the Nepal Micro Hydropower Developers Association (NMHDA). The collaborative effort has resulted in an increasing number of MHP power purchase agreements commissioned in a remarkably short period of time.

## Interconnection of MHP Clusters

Project-to-project interconnection is rarely discussed in the mainstream mini-grid dialogue. However, among MHP practitioners across S/SE Asia clustered-interconnection is expressed as a great need. Because MHP projects typically have a finite power output limit, MHP communities with increasing population and loads face issues in generating enough electricity from the MHP plant. To resolve this, the AEPC with its Renewable Energy for Rural Livelihoods (RERL) initiative supported by the UNDP have overcome technical and institutional challenges to successfully develop three interconnected MHP clusters, each interconnecting two to six projects, where excess electricity from larger plants is used by nearby MHP communities facing shortage. Practitioners in Pakistan, Malaysia, Myanmar, and the Philippines, where there are dense numbers of MHP projects, now look to Nepal for practical knowhow on interconnecting MHP clusters.

## MHP Ownership and Governance

Nepal's hindsight experience in different forms of MHP ownership and governance has led to recent insight and new paths for developing MHP projects. Firstly, with so many existing MHP communities, beneficiaries have started to organize themselves into consumer groups. Such a group is being facilitated by People, Energy & Environment Development Association (PEEDA) to meet the group's request to form an MHP consumers association. The association would serve as a vehicle for strengthening MHP sustainability, including increased productive end use and facilitating interconnection in clusters or to the central grid. Secondly, through Winrock Myanmar's MHP stakeholder exchange supported by the Wisions Initiative, participatory research shows that shifting from user-based group management to cooperatives or small public limited companies can increase the longevity of MHP projects.

Applying this insight regionally, the same conclusion is being noted in MHP experiences of India, Pakistan, Myanmar, Malaysia, Indonesia, and the Philippines. This learning is critical because most community-based MHP projects globally are grant-funded, and therefore rely on user-group based ownership and management. While gaps in technology design, socio-technical issues in operation and maintenance, and/or poor conditions of the watersheds are dominant culprits of MHP failure, Nepal's hindsight reflections reveal that MHP projects that are run as cooperative or public enterprises inherently have increased due diligence that prevents MHP failure. If there is failure, the enterprise-based MHP is economically more resilient and able to return to normal operation in shorter periods because they do not rely on grant or user-group financial inputs that typically require much time to collect, e.g. door-to-door donation collection for MHP repair. In fact, regional practitioners are now eager to learn from Nepal on how to transition existing user-group managed MHP projects into self-sustained enterprises.

## Debt financing for MHP

MHP practitioners in the region that have achieved project financial viability eager to access debt to develop additional MHP projects. However, in most of S/SE Asia contexts there is a large awareness gap between domestic banks and the MHP sector. MHP developers require financing that does not have high collateral requirement, affordable interest rates, and payback periods of 8-10 years. Due to various reason in each country, local banks are not able to enable such financing. However, over the last several years with support from Energising Development, Practical Action, and other partners of the AEPC, Nepal has demonstrated lending to the MHP sector with the establishment of the Micro Hydro Debt Fund (MHDF) and the Central Renewable Energy Fund (CERF). While Nepal's lending to MHP is still developing, the MHDF and CERF are a mere dream for practitioners in Myanmar, Indonesia, and Malaysia. Therefore, Nepal's progress and expertise in enabling debt financing for MHP provide critical inspiration and insight to the S/SE Asia region.

## Enhancing the Value of Local Technology Development

One of the key advantages of MHP is that the technology can be locally developed, spurring the creation of local jobs, skillsets, and technology-based enterprises. In fact, in Nepal, Indonesia, and Sri Lanka, there is an entire local eco-system of masons, electricians, electronic suppliers, civil engineers, turbine manufactures, and plant operators that has resulted from decades of MHP development. Many suppliers now export regionally or globally, and individual experts have become consultants for energy access programs in other countries. In Nepal the work of the NMHDA and PEEDA continue to promote and advance technology development. NMHDA conducts technical trainings for different levels of stakeholders, having established a new training center on the outskirts of Kathmandu. PEEDA is working with the University of Bristol on an action research project to identify how local manufacturing can further advance. Nepal's focus on local skills building and advancing local expertise is one of a few shining examples in the region where the government and international development partners have actively chosen to support local developed technology and local technical practitioners. Practitioners in Pakistan, Myanmar, Malaysia, and Philippines seek similar developments to acknowledge and advance local technology.

## Local Level Energy Planning with GIS Tools

With Nepal's constitutional mandate that energy planning must happen at the municipal level, AEPC and RERL with international partners have started to develop a GIS-based tool to assist local decision makers and communities in conducting informed and analysis-based energy planning. Energy planning based on ground realities and local perspectives are sought after across S/SE Asia contexts, where energy planning is currently based on the myth of a cost-effective, reliable, climate resilient, and equitable central grid for rural electrification. Although local actors know that decentralized renewable energy (DRE) solutions have greater merit than the central grid, they do not have data-based arguments to even enter the debate. In certain countries, national governments have an affinity for DRE but lack data and processes to connect the macro and micro planning. Where GIS-based tools have been developed, they are limited to solar and wind due to lack of GIS tools that can accurately map small-scale hydro and biomass resources. Nepal's AEPC and RERL are working to address these gaps by creating an easy-to-use, reliable, GIS-based tool that local level energy planners can utilize to visualize the current reach and reliability of the central grid, existing DRE mini-grids, locations of un-electrified villages, and the availability of DRE national resource. The effort will make it possible for local decisionmakers to develop well-coordinated, ground-truth based, electricity plans, inclusive of all available DRE. Various practitioners in the S/SE Asia region have embarked on similar paths but with little or no resource and hence progressing very slowly. They seek inspiration from Nepal's progress in developing cost effective, fast, and reliable DRE solutions for energy access.

## Effective Multi-stakeholder Coordination

The multi-disciplinary advancements that Nepal has developed for the small-scale hydropower sector can be attributed to the synergy achieved between multi-stakeholders, including national and municipal government, private sector, academia, donors, civil society, and NGOs. AEPC's role as an effective coordinating agency has proven to be invaluable in preventing parallel and uncoordinated efforts, and instead nurturing the practice of open dialogue, collaborative decision making, and iterative reflections of the outcomes. In most countries of S/E Asia it is just the opposite. There are dismal gaps and lack of coordination between international and local stakeholders, among multi-stakeholders (e.g. donors do not engage with local practitioners), among the multitude of international donors, among ministries and different levels of government, and in some countries among the various NGOs. Nepal's multi-actor achievements provide much hope and learning for those us that see the impact of any rural electrification effort ultimately depends on inclusive and well-coordinated multi-stakeholder processes.

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*Dipti Vaghela co-founded and now manages the Hydro Empowerment Network (HPNET), a multi-stakeholder knowledge exchange and advocacy platform to advance and scale small-scale hydropower. She is continuously inspired by Nepal's micro hydro progress and is grateful that HPNET's founding members and Board include practitioners from Nepal. More information on HPNET is available at www.hpnet.org.*

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# Erosion of hydro-turbine: some preventive design measures and way towards variable speed operation

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In the power plants of Indian sub-continent, excessive sediments carried by Himalayan rivers are a major challenge from operational and maintenance perspectives. Due to hard mineral contents such as quartz and feldspar present in sediment, the turbine parts where the velocity is maximum get eroded. Erosion of turbine ultimately leads to various financial losses, which includes loss of efficiency or drop in power output, cost of repair and maintenance of turbines and unplanned outages of the plant. Recent research works have mostly focused on sediment erosion in Francis turbines due to high vulnerability of these turbines towards erosion. This article focuses on pointing out key findings from recent research activities in the context of sediment erosion in Francis turbines. The findings have been collected through several literatures [Chitrakar et. al, 2016; Chitrakar et. al, 2017; Thapa et. al, 2017; Chitrakar et. al, 2018].

## Sediment erosion of hydraulic turbines

Erosion is a form of wear which is caused by the impacts of solid or liquid particles on a solid surface. Wear in hydraulic machines is, in general, affected by several factors such as properties of the solid particles (sand) like hardness, size, shape, relative density and concentration, properties of the eroded material, the operating condition like flow speed, temperature and impact angle. For a design of any turbines in erosive environment, these parameters have to be taken into consideration. However, the turbines in the power plants of Nepal are exported from abroad. These turbines focuses on high efficiencies, but do not address the problems of sediment erosion. This is because sedimentation is a unique problem of power plants under Himalayan rivers and few regions of Andes and Alps. Considering this localized problem, the turbines need some optimizations, which would minimize the erosion without affecting the rated efficiency significantly. In the past few years, several studies have focused on erosion problems and design optimizations for Francis turbines. Depending upon the nature of the flow in turbines, different components inside a turbine erode with different mechanisms. In the case of Francis turbines, the runner outlet erodes due to high relative velocity of water. At the corners between facing plates and guide vanes, horseshoe or corner vortex causes erosion, forming grooves of the guide vane profile on the plates. This erosion eventually increases the size of the clearance gap, which forms a vortex filament downstream of guide vanes causing erosion at the inlet of the runner blades. This phenomenon is more descriptively defined in sections below.

## Guide vanes of Francis turbines – root cause of several problems

Guide vanes in Francis turbines are present to accelerate the water and maintain the flow at different operating conditions. Along the guide vane, a large portion of the potential energy of the water is converted into kinetic energy. Due to high acceleration, the flow tends to be unstable and in the case when the flow accelerates away from the direction of streamline, the erosion rate intensifies. In guide vanes, a small dry clearance is present to enable movement of the vanes. The clearance gaps between the guide vanes and cover plates tend to increase in size due to the simultaneous effect of secondary flow and erosion in sediment-affected plants. The pressure difference between the two sides of the guide vanes induces leakage flow through the gap. This flow enters into the suction side with high acceleration, disturbing the primary flow and causing more erosion and losses in downstream turbine components. A simplified picture of the leakage flow through the clearance gap and a vortex core traveling inside the runner is shown in Figure 1. This vortex is formed due to mixing of the flow from the pressure side to the low pressure (suction) side forming a rotational component.

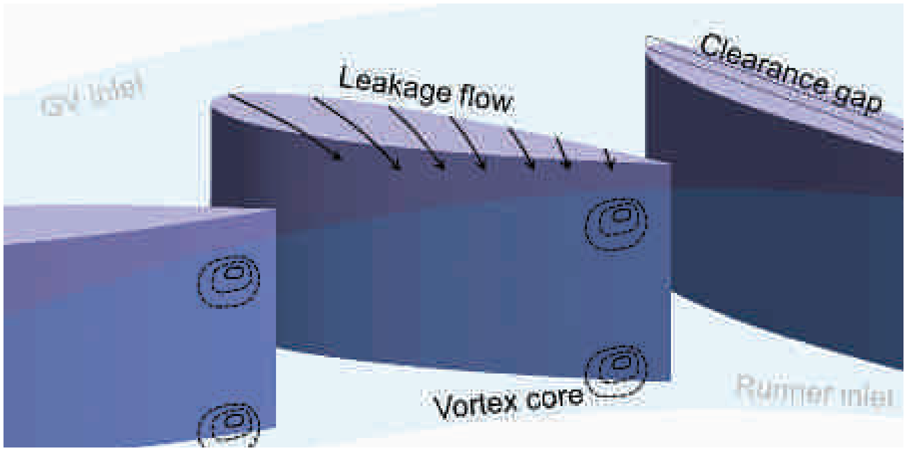


*Figure 1: Leakage flow through the clearance gap and vortex core traced at the runner inlet*

This vortex filament causes several problems in the downstream runner blades. The rotational component of the flow enhances erosion of the runner blade inlet in the sediment contained water. The erosion is also accompanied with cavitation due to localized pressure differences formed due to uneven surface morphology. Apart from the rotor-stator interaction effect, the vortex filament continuously interacts with the runner increasing the chances of fatigue in runner blades. Figure 2 shows the eroded guide vane and runner of Jhimruk HPP and the maintenance works. The guide vanes are mostly eroded at the span ends due to leakage flow discussed above. The eroded parts are welded and then grinded so that the previous surface morphology is maintained. Welded sections can be seen at the runner inlet, towards the ends, which shows that these regions were eroded. The erosion occurred due to the vortex filament from the clearance gaps of the guide vanes. Apart from the runner inlet, the outlet section is also seen to be eroded. This is mostly due to the high relative velocity of the flow in this region.


*Figure 2: Eroded Francis turbine and maintenance of Jhimruk HPP's turbines, 2018*

## Some preventive measures and recent findings

The most common technique for the preventive measures of the erosion is hydro abrasive coatings. Although it was difficult to apply coating on the surfaces of small and medium sized Francis runners, with recent technologies and use of robots, it has become possible to coat them completely. Some recent research works have focused on changing the design philosophy such that the sediments have least impact on the turbine components. Erosion rate is related to the velocity of the flow with the equation . If the velocity inside the turbine can be reduced, the erosion rate can be minimized. However, since the velocity also affects the overall power output and efficiency of the turbine, the parameters need to be optimized so that the best compromise can be made. In the case of runner, the optimization can be done by changing the blade angle distribution from inlet to outlet.

In the case of guide vanes, studies show that the pressure difference between the two sides of the guide vane is the primary cause of the formation of the leakage flow and consequent vortex filament. Several problems in the runner blades as discussed above can be minimized by changing the guide vane profile, such that the pressure difference or blade loading is reduced. It was seen from a rigorous research work that the pressure difference and consequently, the leakage flow can be reduced by using asymmetrical guide vane profiles. The hydrofoils of guide vanes are usually made up of standard profiles such as NACA. In the case of Jhimruk HPP, the guide vanes are NACA0012 hydrofoil, which is symmetrical with thickness 12% of the chord. According to recent studies, it has been shown that by using the same thickness, the profile can be modified to NACA2412 and NACA4412 such that the pressure difference between the two sides will be reduced. Figure 3 shows the flow through the clearance gap of guide vanes having NACA0012 and NACA4412 profiles. The clearance gap in this figure represents the eroded section, which causes the gap to increase in size. It can be seen that in NACA0012, which is the reference profile in the plant, induces leakage flow due to the pressure difference between the two sides of the guide vane. In NACA4412, the leakage flow is reduced, which consequently decreases the intensity of the secondary flow. Reduction in the leakage flow was seen to increase the performance of the turbine, in terms of higher efficiency and lower erosion of runner.

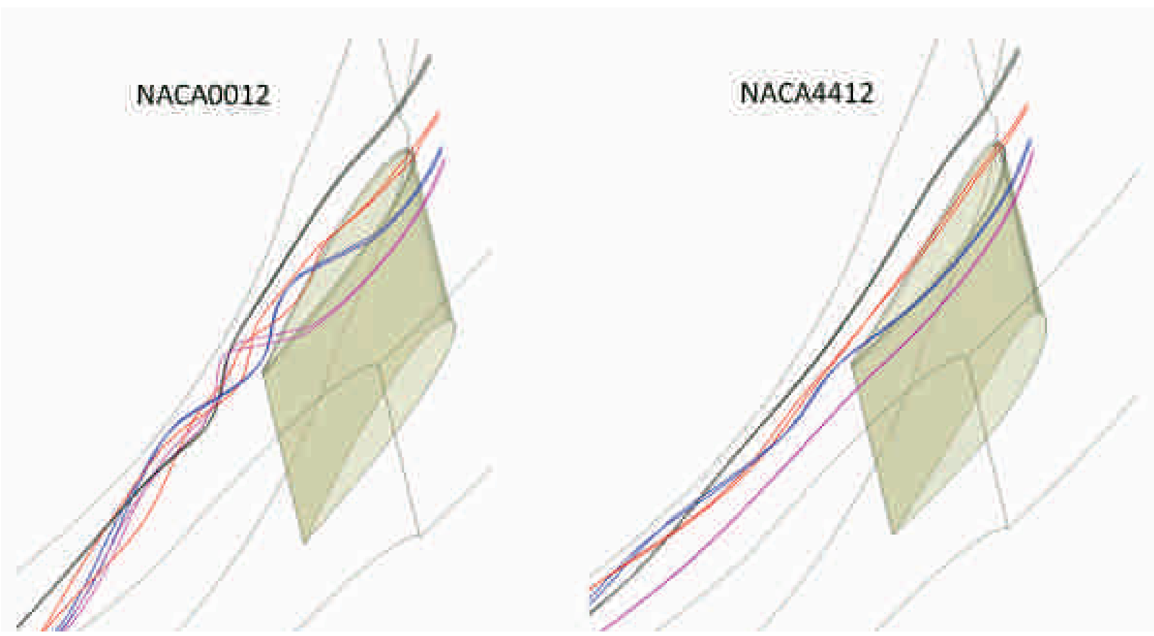


*Figure 3: Leakage flow through guide vanes in NACA0012 and NACA4412*

Variable speed operations of turbines have been one of the latest discussions in the current hydropower industries. This means that instead of using generators with constant pole pairs, the variable speed turbines will have asynchronous generators connected to rectifiers and inverters. This technology is currently used in pumped-storage power plants to make efficient use of the available energy. By using such turbines, it has been shown that the efficiency in off-designed operations can be improved by varying the speed. In the case of such turbines, the rotational speed may control the flow, giving a chance of removing or using fixed guide vanes in the design. To make it possible, the turbines will have to be redesigned, such that the reaction ratio at the inlet of the runner is maintained. By using such turbines in sediment affected projects, there is a great possibility of eradicating all the problems originating from the guide vanes.

## References


Chitrakar, S.; Neopane, H.P.; Dahlhaug, O.G. Study of the simultaneous effects of secondary flow and sediment erosion in Francis turbines. Renewable energy 2016, 97, 881-891

Chitrakar, S.; Thapa, B.S.; Dahlhaug, O.G.; Neopane, H.P. Numerical and experimental study of the leakage flow in guide vanes with different hydrofoils. Journal of Computational Design and Engineering 2017, 4, 218-230

Chitrakar, S.; Neopane, H.P.; Dahlhaug, O.G. Particle Image Velocimetry Investigation of the Leakage Flow Through Clearance Gaps in Cambered Hydrofoils. Journal of Fluids Engineering 2017, 139, 091201

Thapa, B.S.; Dahlhaug, O.G.; Thapa, B. Sediment erosion induced leakage flow from guide vane clearance gap in a low specific speed Francis turbine. Renewable Energy 2017, 107, 253-261

Chitrakar, S.; Dahlhaug, O.G.; Neopane, H.P. Numerical investigation of the effect of leakage flow through erosion-induced clearance gaps of guide vanes on the performance of Francis turbines. Engineering Applications of Computational Fluid Mechanics 2018, 12, 662-678

# A study of operational micro-hydropower sites in Nepal

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## Introduction and motivation

Throughout Nepal, there are more than 3,300 micro-hydropower plants (MHPs) providing a total of 30MW of power to rural communities not connected to the national grid (Association). The turbines that drive these plants have been designed and manufactured in Nepal since the 1960s (Khennas, 2000). Once an installation is complete, members of the local community become responsible for both the technical operation of the plant and its management. Previous research has shown that the turbines and civil structures of hydropower plants often vary in quality (Khadka & Maskey, 2012; Kumar, Yamashita, Ajoy, Shrestha, & Yadav, 2015). In addition, the approaches taken in maintenance and plant management vary considerably from one plant to the next (Barr, 2013).

Poor technical or economic plant performance has a significant impact on the lives of people connected to the plant. Without a reliable source of electricity, consumers must revert traditional forms of energy for lighting and are deprived of opportunities for income generation. This paper presents a summary of a study conducted by PEEDA and the University of Bristol during November 2017 and March 2018. The study combined qualitative and quantitative methods to evaluate how operational micro-hydropower plants in Nepal are perform from technical, social and economic perspectives.

## Method

During the study, 24 sites in the neighbouring districts of Baglung and Gulmi were visited. The sites visited included 18 with Crossflow turbines and 6 with Pelton turbines. At each site, interviews were conducted in Nepali with a consumer, management representative and plant operator. The intention of the interviews was to understand attitudes towards the hydropower plant and record the approaches to management and maintenance.

In addition, for 10 of the sub-systems (intake, de-silting bay, channel, forebay tank, penstock, internal pipework, turbine, generator, control panel and the powerhouse), a two-part assessment was conducted. Qualitatively, the condition of sub-systems was recorded. Quantitatively, an assessment of maintenance was also conducted. For each of these sub-systems, a marking scheme was used which assessed the quality of maintenance from 1 (very bad quality of maintenance) to 5 (very good quality of maintenance) was used. This marking scheme was developed based on available literature and an example for the de-silting bay sub-system is shown in Table 1.

| | *Description* | *Score* |
|---|---|---|
| **De-silting bay** | **Very well maintained. Good evidence of regular preventative maintenance.**Desilting bay is clean, free from erosion with no obvious cracks visible. Minimal silt build up. | 5 |
| | **Evidence of effort to maintain the sub-system but without following a schedule closely.**Some dirt, debris and a small amount of erosion is visible. Cracks may be present but they are small. Any obvious leaking is minor. Some silt is obvious in bottom of bay. | 3 |
| | **Poorly maintained. Preventative maintenance is rare.**Intake is heavily contaminated with obvious signs of erosion. Cracks are significant and/or leakage is obvious. Significant build up of silt in bottom of bay. | 1 |

*Table 1 - Marking scheme for a de-silting bay*

## Results

The quality of maintenance varied considerably across the 24 sites with a range of 2.3 and a mean maintenance score of 3.1. Figure 1 shows the maintenance score at each of the sites. Of the 9 worst sites, 7 had untrained operators.

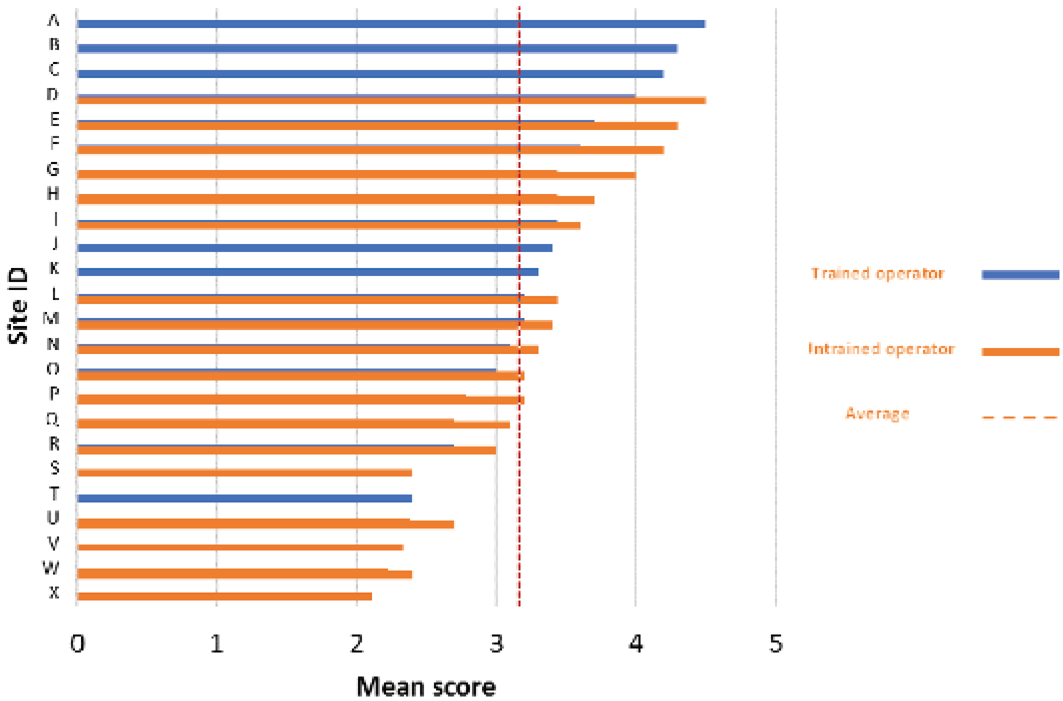


*Figure 1 - Average maintenance score by site*

In Figures 2 and 3, the range in quality of maintenance can be visually observed. Across all sub-systems, the site shown in Figure 2 and Figure 3 received average maintenance scores of 4.3 and 2.3 respectively. Comparing the two sites, the site shown in Figure 2 had a tidy and organised powerhouse, the turbine and pipework paintwork was clean and free of rust and there is a tool rack on the wall. Conversely the site shown in Figure 3 had a very dirty powerhouse with lots of items stored inside making it difficult to work on the turbine. During site visits, the sub-systems with lowest average maintenance scores were the turbine, canal and forebay tank. Common problems with these sub-systems included mis-alignment in the transmission, cracks in the walls of the civil structures and a large build up of silt.

*Figure 2 – A site with good maintenance*

*Figure 3 - A site with poor maintenance*

Domestic consumers were using electricity from the MHP for a range of uses. Figure 4 shows the domestic uses of electricity.

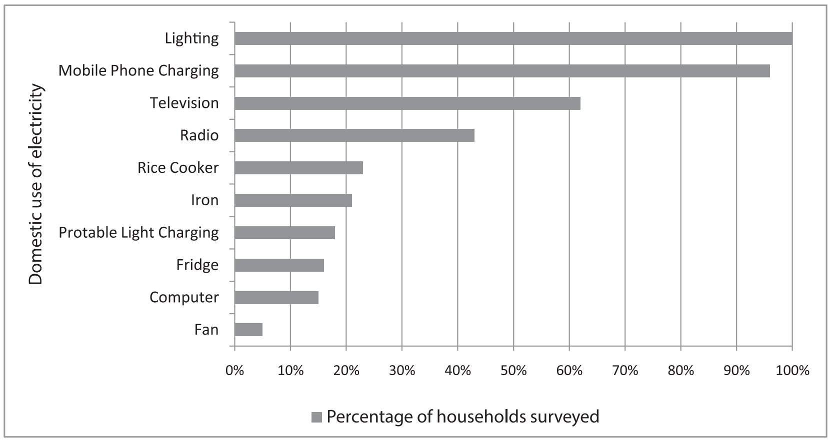


*Figure 4 - Domestic uses of electricity*

Comparing to data from a World Bank study in 2009, electricity use in rural communities has developed. In 2009, use of radio and television was 3.8% and 7.6% respectively with no households reporting using rice cookers, fridges or computers. At the sites visited, there were diverse end uses of electricity as shown in Table 2. These end uses have been grouped in to traditional productive end uses, commercial and community services.

*Table 2 - End uses of electricity at the 24 sites*

| *Commercial services* | *Total* | | *Community services* | *Total* |
|---|---|---|---|---|
| Grocery shop | 353 | | School | 84 |
| Tea shop | 164 | | Hospital/health clinic | 40 |
| Bank/Co-operative | 28 | | Local government office | 35 |
| Clothing shop | 31 | | Post office | 7 |
| Hotel/Lodge | 16 | | Community centre | 9 |
| Barber shop | 9 | | Temple | 2 |
| Meat shop | 8 | | ***Productive end uses*** | ***Total*** |
| Telecom tower | 9 | | Flour/grain mill | 85 |
| Radio tower | 5 | | Poultry Farm | 58 |
| Computer training centre | 3 | | Furniture making | 37 |
| Stationary shop | 3 | | Welding workshop | 19 |
| Irrigation pump | 3 | | Bakery | 10 |
| Movie hall | 1 | | Dairy shop/factory | 4 |
| Petrol pump | 1 | | Cotton factory | 1 |
| TV cable office | 1 | | Stone thresher | 1 |
| Workshop/Garage | 1 | | Noodle factory | 1 |

At all but one of the sites visited during the study, bills were charged based on electricity meter readings. The tariffs for these sites used a base rate for a specific number of units (kilowatt-hours) with additional electricity consumption charged on a per unit basis. The base rates varied considerably from 4 kWh for NPR 100 to 20 kWh for NPR 100. Table 3 compares the minimum, median and maximum prices across all the sites for minimum, median and maximum power consumption.

*Table 3 – Electricity tariffs*

| Estimated monthly consumption (kWh) | Minimum price (NPR) | Median price (NPR) | Maximum price (NPR) |
|---|---|---|---|
| **7** | 50 | 100 | 200 |
| **15** | 100 | 120 | 225 |
| **60** | 200 | 492 | 900 |

The interviews with plant managers revealed the number of connected households and end uses at each site. Figure 5 plots the number of connected households and end uses against the rated power of the site. The size of the marker corresponds to the number of connected end uses. There is a strong positive correlation between the rated power and the number of connected households. For connected end uses, the trend is less positive with more variation in the size of markers for sites with similar rated powers.

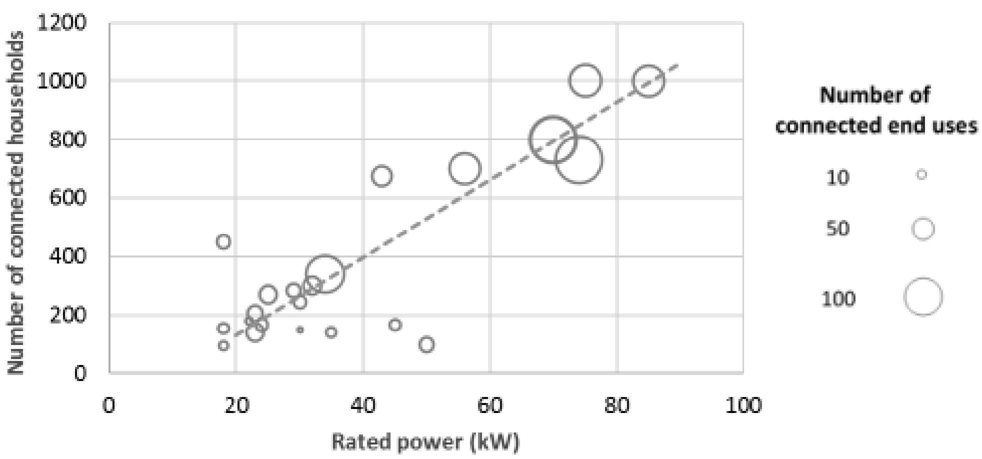


*Figure 5 - Number of connected households and end uses against rated power*

## Discussion

The results from the maintenance assessment demonstrated that trained operators tended to deliver a higher standard of maintenance than untrained operators. At 6 of the sites, untrained operators had replaced operators who had received training but had moved away for work. The replacement operators were often unaware of the responsibilities that they had to fulfil as the operator. As a result, daily preventative maintenance tasks were not completed leading to the low scores for maintenance. There were also problems witnessed that were initiated prior to the commissioning of the plant. For example, poorly shaped de-silting bays occur due to bad practice during construction rather than carelessness in maintenance. Other problems, such as leakage and misalignment are detrimental to the performance of plants. Both of these issues reduce the efficiency of turbines. As this study was conducted on site whilst the turbine was in operation, it was not possible to identify when these issues first started to occur.

The combination of domestic and commercial uses of electricity meant that MHPs were valued by the communities that they serve. Consumers described the financial, time saving and health benefits that resulted from connection to an MHP. At 79% of the sites, management representatives answered “Yes” or “Yes mostly” when asked if consumers paid regularly. Meanwhile, responses from consumers demonstrated that there was social pressure to pay and an awareness of the consequences of failing to pay.

The variation in tariff structures suggest that similar plants could be receiving differing incomes. Without enough money to pay for salaries, repairs and spare parts, MHPs struggle to deliver reliable electricity sustainably. In addition, the number of connected households and end uses affects the sustainability of the plant. In Figure 4, there is a cluster of 4 sites below the line of best fit that have fewer connected households and end uses than the trend. The sustainability of these plants may be threatened if significant technical problems occur as they may not be generating sufficient income. The sites with rated powers above 50kW tend to have a more consistent number of connected households and end uses. In this study, these larger sites were providing power to towns or larger villages with a higher population density. In these areas, it is easier to maximise the number of household connections and there are plenty of businesses that desire an electricity connection. The managers of the 6 sites with rated power above 50kW all reported that they had sufficient money to pay for repairs. Amongst smaller sites, 69% reported that they had experienced some difficulty in paying for repairs.

## Conclusion

This study demonstrated that for rural communities, MHPs are a valuable source of electricity in the home and in the wider community. Their positive effect on quality of life means that most consumers are willing to pay; the use of electricity meters means that consumers need only pay for the electricity that they use. Despite the good management structures witnessed, some plants experience difficulties in paying for repairs. These sites tend to power more remote villages where there are fewer businesses and tariff collection is more difficult. Technically, there is significant variation in the quality of maintenance at MHPs in Nepal. It is worth considering that the sites visited in this study were located in a district well known for hydropower which is accessible in less than a day from Butwal, Nepal's hub for hydropower. The common problems identified such as mis-alignment and high quantities of silt require greater consideration during maintenance and operation. However, attention is also required during earlier stages of the project process to minimise the occurrence of these issues.

*This article presents a brief summary of the study conducted jointly by the University of Bristol and PEEDA. The results of this study have been presented at International Conference for the Development of Renewable Energy Technology (ICDRET) 2018 in Kathmandu, Nepal and the Global Humanitarian Technology Conference (GHTC) 2018 in San Jose, USA.*

## References

Association, N. M. H. D. MH in Nepal. from http://microhydro.org.np/mh-in-nepal/

Barr, J. (2013). Improving Maintenance of Micro Hydropower Systems in Rural Nepal: Uppsala University.

Khadka, S. S., & Maskey, R. K. (2012). Performance study of Micro-hydropower system in Nepal. Paper presented at the International Conference In Sustainable Energy Technologies (ICSET), Kathmandu.

Khennas, S., and A. Barnett. (2000). Best Practices for Sustainable Development of Micro Hydropower in Developing Countries. London: DFID/ITDG.

Kumar, P., Yamashita, T., Ajoy, K., Shrestha, A., & Yadav, A. (2015). Nepal-Scaling up electricity access through mini and micro hydropower applications: a strategic stock-taking and developing a future roadmap. Washington: World Bank.

# Bio-slurry: A Good Fertilizer for Agricultural Production

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## 1. Introduction

Organic matter plays an important role in agriculture because of its beneficial effects in supplying plant nutrients, enhancing the cation exchange capacity, improving soil aggregation, increasing water holding capacity of soils and stabilizing its humus contents. Bio-slurry has proved to be high quality organic manure compared to farm yard manure (FYM), as digested slurry has a higher concentration of plant nutrients while farm manures, if poorly stores, often lose nutrients, such as nitrogen due to evaporation and leaching.

In countries where biogas technology is well developed, for instance in China, India and Nepal there is evidence that productivity of agricultural land can be significantly increased with the use of bio-slurry. The Biogas Support Programme (BSP) in Nepal initiated a Slurry Extension Pilot Programme (SEPP) in 1995, which subsequently developed a full - fledged Slurry Extension Programme (SEP) in 1997.

## 2. Characteristics of Digested Slurry

When fresh cow dung is allowed to dry approximately 30 – 50 percent of nitrogen escapes within 10 days. The nitrogen lost from digested slurry within the same period amounts to 10 – 15 percent. The value of slurry as fertilizer, if used directly in the field as it comes out of the plant, is higher when it is used after being stored and dried (Moulik, 1990). Cattle dung contains about one percent total nitrogen. During anaerobic digestion 25 - 30 percent organic matter is removed as biogas and hence the nitrogen percentage is raised to 1.3 percent.

The composition of bio-slurry from a biogas plant depends upon several factors: the kind of dung (e.g. animal or human), breed and age of animals, types of feed and feeding rate and the amount of water added. Bio-slurry can be used to fertilize crops directly from the plant or added to a compost heap, mixed with other organic materials. Bio-slurry is an already-digested source of animal waste. More nitrogen can be added to the bio-slurry as urine (animal or human) and this can also speed up the compost-making process. This can improve the carbon/nitrogen (C/N) ratio in the compost if this is an issue in the digester. Normally the composition of the bio-slurry consists of 93% water and 7% of dry matter, of which 4.5% is organic matter and 2.5% inorganic matter. The bio-slurry also contains elements such as phosphorous, potassium, zinc, iron, manganese and copper. Copper has become a limiting factor for the fertility of many soils. Bio-slurry can be used to build healthy fertile soil for crop production(Warnars & Oppenoorth, 2014).

Plants need different nutrients for growth and to enable enzymatic processes. The availability of nutrients is influenced by the climate and the soil composition. Soil can be considered from various aspects, such as its physical, biological and chemical properties. The chemical features can be divided into nutrient availability, pH value, caution exchange capacity (measuring fertility), oxidation reduction and salinity. Mineral nutrition includes the supply, absorption and utilization of essential nutrients for growth and yield of crop plants.

The following table shows a typical analysis result of nutrients from FYM, compost and slurry obtained from a study conducted in India which clearly shows the superior fertilizing value of the digested slurry (Gupta 1991).

*Table 1: Analysis results of the nutrients*

| Nutrients | FYM | Compost Manure | Digested slurry |
|---|---|---|---|
| | Range % | Range % | Range % |
| Nitrogen | 0.5- 1.0 | 0.5- 1.5 | 0.4- 1.8 |
| $P_2O_5$ | 0.5- 0.8 | 0.4- 0.8 | 1.1- 2.0 |
| $K_2O$ | 0.5- 0.8 | 0.5 - 1.9 | 0.8 – 1.2 |

The result of similar study conducted in Nepal to compare the chemical characteristics and nutrients contents of different forms of bio-slurry are presented below:

*Table 2: Nutrient contents of bio-slurry*

| Form | pH | Moisture % | Total N % | DM % | C:N Ratio | $P_2O_5$ % | $K_2O$ % | Remarks |
|---|---|---|---|---|---|---|---|---|
| Composted slurry | 7.82 | 65.02 | 1.31 | 25.07 | 11.00 | 1.18 | 0.88 | Wet basis |
| | | | 3.75 | 71.70 | | 3.37 | 2.52 | Dry basis |
| Sun–dried Slurry | 7.44 | 40.66 | 1.73 | 24.53 | 8.00 | 0.69 | 0.68 | Wet basis |
| | | | 2.92 | 41.46 | | 1.17 | 1.15 | Dry basis |
| Fresh Slurry | 7.16 | 93.03 | 0.06 | 4.55 | 44.00 | 0.04 | 0.06 | Wet basis |
| | | | 0.87 | 65.66 | | 0.58 | 0.87 | Dry basis |
| Fresh Dung | 8.11 | 81.25 | 0.30 | 15.47 | 30.00 | 0.78 | 0.42 | Wet basis |
| | | | 1.60 | 82.46 | | 4.16 | 2.24 | Dry basis |

The above table clearly illustrates the marked enrichment of composted slurry in comparison to other forms in terms of their nutrient contents (Baracharya 1997). However, these results suggest unexpectedly low proportions of N, P, and K for fresh dung and fresh slurry. This needs further verification through detailed and comprehensive research and analysis.

## 3. Plants Nutrients Available in the Slurry

Like animals, all plants need food for their growth and development. There are 16 essential nutrient elements needed for their growth and development. These elements are carbon, hydrogen, oxygen, nitrogen, phosphorus, potash, calcium, magnesium, sulfur, iron, zinc, manganese, cupper, boron, molybdenum and chlorine. In the absence of these nutrients, the plant growth will be abnormal or restricted(Araya & Edwards, 2006).

Nitrogen helps in the growth and development of the plant and makes the leaves green. Phosphorus helps in the development of seeds and fruits and also helps growth and development of roots. Potash (Potassium) helps the plant to protect itself from diseases and reduce wilting.

Some of the major key features of biogas slurry are:

- Biogas slurry is available more quickly than if the animal dung is composted;
- There is less nitrogen lost in biogas slurry due to the anaerobic conditions in a biogas plant;
- If night soil or cattle urine is added to the biogas plant, the availability of nitrogen and phosphorus in the biogas manure is increased.

## 3.1 Properties of slurry manure

- Completely fermented slurry has no smell, flies and insects are not attracted to it;
- If biogas slurry is used, the number of white termites found in the soil is reduced. In addition, the growth of weeds is also less in a field where slurry manure is used;
- Slurry manure has more nutrients compared to compost and fresh manure;
- Application of slurry manure in the field increases humus in the soil which ultimately improves the soil quality and productivity;
- The slurry also helps in protecting plants from many diseases.

## 4. Storage and Uses of Slurry

The availability of the nitrogen in the slurry is 100% when fresh slurry is applied immediately and covered with soil. If the slurry is semi-dried, the availability is reduced to 85%. If the slurry is fully dried, the availability is only 65% (NBPA, n.d.).

The digested slurry can be applied as follows:

- Direct application can cause seedlings to grow too fast and fail;
- Washed into the fields through irrigation channels;
- Spread over the soil in the dried form; and
- Mixed with other organic materials to make compost, which is then spread on the land.

The effectiveness of the slurry compost in the crops is as follows:

- Improves the soil structure;
- Improves the fertility of the soil;
- Improves the capacity of water storage in the soil; and
- Helps to make bacteria active in the soil.

## 4.1 How to make compost

There are various ways of making compost but in Nepal the following practices are very common:

- Two compost pits are dug about one meter away from the outlet chamber of a biogas plant. The volume of these pits should be approximately equal to the total volume of the biogas plant and the depth of the pit should not be more than one meter otherwise it will be risky to children and animals. Likewise, the gap between the two pits should be more than half a meter. The pit should be slightly tapered, narrow at the bottom and wider on top. The sides of the pit should be raised about 15 cm above the ground, so that ground water does not flow inside the pit.

- Once the pits are made, put a 15 – 20 cm thick layer of dry leaves, plant litter, grasses, straw and other organic material in one of the pits to absorb water from the slurry which prevents the leaching of plant nutrients.
- Slurry from the biogas plant will flow over the bed of dry matter and should be periodically covered with more straw or dry leaves so that it will not be dried by sunlight.
- Layers of slurry and dry organic matter are built up over time until the pit is filled to the point it is level with the top of the pit sides.
- Small huts can be made from sticks and leaves over the top of the compost pits. Shade can also be provided by growing some creeping vegetables over sticks to prevent the compost from being in direct sunlight.
- After one month, the compost should be turned over and then covered with dry grass or mud. Turning should be done in every 15 days.
- Once the first pit is full, a similar procedure can be followed for the second pit. After two to three months the compost in the first pit is ready to be applied in the field.

To prevent nutrient loss from the biogas slurry, it should be either stored in a pit or used to make compost, as above. It should be protected from direct sunlight. When the compost is not being use in the fields, it should be kept in a pile and covered with dry leaves or mud. Normally compost should be applied at a rate of about 500 kg per ropani or 6500 kg per bigaha.

## 5. Effects of Various Fertilizers on Vegetable Crops

A study was conducted by the author in Nepal on a comparison of the effects of various fertilizers on crops of potatoes, onions, cabbage, lady's fingers and wheat. It showed that the use of biogas slurry increased the yield of potatoes by 17%, onions by 8.5 %, cabbage by 10.2%, lady's fingers by 13.3% and wheat by 36.6 % compared to a control(Devkota, 2001). The use of biogas slurry mixed with a chemical fertilizer (urea) showed better yields as shown in Table 3.

*Table 3: Comparison of effects of various fertilizers on vegetables and cereals in yield, Source: (Devkota, 2001)*

| S.N. | Treatment | Potatoes | Onion | Cabbage | Lady's finger | Wheat |
|---|---|---|---|---|---|---|
| | | Increase % | Increase % | Increase % | | |
| 1 | Control | - | - | - | | |
| 2 | Chemical (urea) | 25.0 | 11.4 | 28.4 | 16.7 | 54.6 |
| 3 | Bio-Slurry | 17.0 | 8.5 | 10.2 | 13.3 | 36.6 |
| 4 | Slurry + chemical (urea) | 28.3 | 25.0 | 32.4 | 20.0 | - |

Another study was carried by Mr. Gurung (Gurung, 1998) which showed that the effects of biogas slurry is better when used on vegetable crops compared to that of fresh dung and farm yard manure (FYM).The results are shown in Table 4.

*Table 4: Comparison of effects of various fertilizers on cabbage, mustard and potato in yield, Source:(Gurung, 1998)*

| S.N. | Treatment | Cabbage | Mustard | Potato |
|---|---|---|---|---|
| | | Increase % | Increase % | Increase % |
| 1 | Control | - | - | - |
| 2 | FYM | 18.67 | 25.80 | 25.33 |
| 3 | Slurry | 20.63 | 45.75 | 34.75 |
| 4 | Slurry + single superphosphate | 20.70 | 49.75 | |
| 5 | Slurry + rock phosphate | 15.90 | 35.25 | - |
| 6 | Slurry + potash | 24.00 | - | - |
| 7 | FYM + Potash | - | 33.98 | - |

Another similar study conducted by Mr. Gurung (Gurung, 1998) compared the effects of various fertilizers on crops of cabbage, mustard and potato. The yield results showed that the use of biogas slurry increased potato yields by 34.75%, mustard yields by 45.75% and cabbage by 20.63% in comparison with the control crops. Likewise, use of FYM increased potato by 25.33%, mustard by 25.8% and cabbage by 18.67% with control as shown in the above table.

# 6. Conclusions and Recommendations

## 6.1 Conclusions

A biogas digester provides not only clean and cheap energy, but also produces a good organic fertilizer for crops. Indeed, biogas slurry is an excellent organic fertilizer and is an excellent substitute for farm yard manure. Biogas digesters and biogas slurry contribute to building organic bridges between culture, geography, and (existing/traditional) farming practices.

Biogas-slurry can be a solution to the challenges the organic animal husbandry sector is facing with regards to (organic) waste, fertilizers and composting. Especially for smallholder farmers, this is an interesting solution to meeting not only farming challenges (the requirement for fertilizer) but also energy challenges and access (renewable energy from biogas). Therefore, the use of biogas and biogas-slurry should be stimulated as much as possible.

Because compost is made up of humus, it can be used for improving the soil as it not only provides plant nutrients that are released throughout the growing season, but also builds up the structure of the soil. The plant nutrients are held within the humus until they are released when the organic matter in the humus decomposes. The plant nutrients then dissolve in the water in the region of the soil close to the surface and so are easily taken in by the roots of the crops.

Biogas-slurry improves the soil structure by breaking up lumps so that plant roots can easily reach down into the soil. In sandy soil, the humus makes the sand particles stick together. This reduces the size of the spaces (pores) so that water stays longer in the soil. In clay soils, the humus surrounds the clay particles making more spaces (pores) in the soil so the root systems of plants can reach the water and nutrients that they need, and air can also move through the soil. Therefore, heavy clay soils become lighter and sandy soils become heavier, soil that has had compost added to it is easier to work, i.e. to plough and dig.

Biogas-slurry improves the moisture-holding capacity of soil. The humus is a dark brown or black soft spongy or jelly-like substance that holds water and plant nutrients. One kilogram of humus can hold up to six litres of water. It helps to control weeds, pests and diseases. When weeds are used to make compost, the high temperature of the compostmaking process kills most, but not all, of the weed seeds. Fertile soil produces strong plants able to resist pests and diseases. When crop residues are used to make compost, many pests and disease cannot survive to infect the next season's crops.

Bio-slurry helps the soil resist erosion by wind and water. This is because water can penetrate the soil more effectively and this can stop showers building up into a flood. This also reduces splash and sheet erosion. Soil held together with humus cannot be blown away so easily by wind.

Compost helps farmers to improve the productivity of their land and their income. It is made without having to pay cash or borrow money, i.e. farmers do not have to take credit and get into debt as they do when purchasing chemical fertilizer. However, to make and use compost properly, farmers individually or in groups have to work hard.

## 6.2 Recommendations

For the success of the slurry program in the project area, the following points need to be considered as recommendations:

- Awareness to be created to prepare, store and use the slurry manure;
- Organic fertilizer selling centers to be developed in each communities and markets of such manure to be explored;
- Biogas owners or farmers need to be trained for agricultural production using bio-slurry and composting;
- Government should release/advocate such programs through radio/TV broad casting programs.

## References

Araya, H., & Edwards, S. (2006). The Tigrai Experience. A Success Story in Sustainable Agriculture. Environment & Development Serious(4).

Devkota, G. P. (2001). Biogas technology In Nepal: A sustainable source of energy for rural people: Bindu Devkota.

Gurung, B. (1998). Training programme on proper use of slurry for the technical staff of SNV/BSP. In A training manual (Ed.).

Moulik, T. K. (1990). Diffusion of Biogas Technology: Strategics and Policy. Paper presented at the International Conference on Biogas Technologies and Implementation Strategy Report

NBPA. Nepal Biogas Promotion Association. Retrieved 15th September, 2018, from https://sites.google.com/site/nepalbiogas/about

Warnars, L., &Oppenoorth, H. (2014). A study on bioslurry results and uses. BukuPaket. TerbitMaret.

# Prospects and Challenges of Municipal Solid Waste Management

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The degree of urbanization and socioeconomic growth are often-cited culprits influencing municipal solid waste generation rates. Urban space in Nepal is growing at the rate of 3.2% as of 2017 with 19% of its population living in urban areas. The urban explosion in the recent years has not only led to competition for available land space but also generated more wastes. For the urban sanitation and environment, proper management of solid waste is essential. But many municipalities are not able to adequately manage the generated wastes due to lack of infrastructures, technical and financial back up as well as lack of government and public awareness.

As per the study conducted by the ADB in 2013, the average municipal solid waste (MSW) generation of 58 municipalities in Nepal studied was 317 grams per capita per day and 56 % of this generated MSW comprised organic waste. The organic fraction of municipal solid waste can be used to generate biogas and produce organic fertilizer. Also, inorganic waste like paper, plastic, glass and metals can be recycled and reused. This reduces the organic material that would probably be concealed in the landfill site and also partially cuts off the import of inorganic material. In 2017/18, WindPower Nepal Private Limited carried out a feasibility study to determine the technical and economic viability of waste-to-energy plants in several municipalities of Nepal (Damak, Hetauda, Birtamode, Dhulikhel and Gorkha). The findings indicated Biogas as a viable option for managing organic waste.

Municipalities are struggling to manage the mounting piles of solid waste generated. During our feasibility study, we observed several challenges they are facing in waste management. The Municipalities do not have any integrated solid waste management plan. In addition, irregular collection services, the low collection efficiency of the municipalities i.e. less than 50 % of the total generated waste is collected, use of old vehicles and equipment to collect and dispose of the waste, lack of skilled manpower, knowledge and appropriate technology, lack of transfer station and sanitary landfill site are some of the challenges that municipalities are facing for effective waste management. Out of 263 municipalities, only Kathmandu, Pokhara, Lalitpur, Dhankuta, Ghorai and Tansen have the sanitary landfill for waste management. The rest of the Municipalities practice open dumping mostly at the outskirts of the city area or at the river banks. The current practice of the illegal dumping of solid waste might create a serious environmental and public health problem. In addition, changing lifestyle, consumer behaviour and poor attitude towards waste management are major setbacks to solid waste management. The municipalities have initiated the source segregation and proper storage of waste by providing dustbins in different places, but people resort to litter plastic waste and pet bottles into gutters and road side. Reduction at the origin, on site handling, storage and processing, collection, transfer and transport, processing and recovery and final disposal are the basics of solid waste management. Waste segregation at source is the most important phase in of solid waste management process. However, our study reveals very few households segregate their waste. As most of the municipalities lack their own transfer station, waste segregation takes place at the vehicle itself and only a small portion i.e. 15 - 20% of the recyclable waste is separated. Discussion with the key stakeholders in several municipalities indicates, if a transfer station is made in each municipality, the segregation of recyclable waste would increase up to 40-50 %.

Nepal government now has a federal structure and the local governments are given management authority and responsibility to manage the waste generated in their municipality. Thus, each municipality should cater waste as a business opportunity and be aware of the existing technologies for managing the waste. The central government should work on the capacity enhancement of the newly formed municipalities through various trainings and workshops on sustainable waste management and provide the required equipment and bear financial expenses involved in managing the solid waste.

Installation of waste-to-energy plants is a win-win endeavour. It generates energy making us less dependent on imported fuel, produces organic fertilizer, creates job opportunities which uplift the economic standard of the local people and aids climate change mitigation and sustainable solid waste management . The Government of Nepal has been supporting promotion and development of biogas technology through the provision of subsidies for domestic as well as commercial biogas plants. The Alternative Energy Promotion Centre (AEPC) provides 40% of the total cost as the subsidy for the large biogas plant. For domestic biogas plants using the kitchen and other bio-degradable waste with capacity $4m^3$ or less, Government of Nepal has the provision of the subsidy amount up to 50% of the total cost. More than 74 % of households use solid fuel as the energy source for cooking and liquid petroleum. Gas is used by more than a quarter of households. In such a scenario, Biogas production provides access to the sustainable clean energy and helps in achieving Goal 7 of the Sustainable Development Goals.

In Nepal, Biogas has not become a lucrative sector in terms of commercial usage but for managing waste and reducing dependency on fossil fuels, it would benefit largely. The local governments should encourage proper sustainable mechanisms such as waste-to-energy for the management of large volume of municipal solid waste and private sectors to invest in it.

## References


ADB, 2013. Solid Waste Management in Nepal: Current Status and Policy Recommendations. Asian Development Bank.

Dahal, Y., & Adhikari, B. (2018). Characterization and Quantification of Municipal Solid Waste in JeetpurSimara Sub-Metropolitan City, Nepal. Hydro Nepal: Journal of Water, Energy and Environment, 22, 45-47.

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

National Planning Commission, 2015: Sustainable Development Goals, 2016-2030, National (Preliminary) Report. Government of Nepal, National Planning Commission, Kathmandu, Nepal.

Shakya, S., Khatiwada, N., & Thapa, A. (2013).Diagnostic Report on SWM in Nepal: Key Issues, Challenges and Way Forward.

The World Bank 2018. World Urbanization Prospects: 2018

# Study of a Waste Management Project in Rural India

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## 1. Project coverage

The project covers 11 villages of Orohalli Grama Panchayat (GP)

- Total households = 1400
- Total population = 6132
- Project Place or Location: Orohalli Panchayat, Karnataka, India
- Project Period: September 2017 to August 2018
- Project funded by: Juniper Networks Pvt Ltd
- Project implemented by: Saahas, Bangalore

## 2. Situation before Project Intervention

Most parts of rural India have no waste collection mechanism in place. Waste is either dumped in the outskirts of the villages or burnt periodically at household level or at the village outskirts. In countries like India or Nepal, where more than 60-70% of its people reside in rural areas, improper waste management is leading to health hazards, pollution, and various other problems, due to littering and burning of waste.

Orohalli Panchayat was no exception, until September 2018. The Panchayat had no waste collection system, and thus dry waste was either littered around streets or burnt. Drains were filled with dry waste and residents were ignorant about the ill effects of burning waste. We can also attribute the habit of littering in residents due to non-availability of a waste collection mechanism. However, wet waste is not a problem in Orohalli GP, as

wet waste is either fed to livestock or put into backyard 'tippes', which gets converted into compost, over time.

## 3. Aim of the waste management project

- To bring about behavioral change in residents, to segregate wet and dry waste at source, and to prevent littering.
- To spread awareness about the pollution caused and ill effects due to open burning of plastic and other waste.
- Weekly collection of dry waste from households.
- To provide necessary infrastructure for sorting dry waste.
- To supply non-recyclables to cement factory for co processing.

## 4. Awareness Sessions

Awareness to people, forms the basis of the project. Various awareness and training sessions were conducted to the different stakeholders in the Orohalli GP. Training sessions were conducted to the Panchayat members and staff members of the project, during the initial stages of the project, whereas awareness sessions have been conducted in Anganawadi (kindergarten), schools and women self-help groups, throughout the duration of the project.

- Awareness and training session to Panchayat members and staff members
- Door to Door project awareness sessions
- Door to Door Blue Bag distribution, to store dry waste in houses, shops and schools
- Awareness sessions with Anganawadi, Schools and self-help groups: Reaching out to school children is very important, as they will be the ones, taking the idea and the cause forward

## 5. Waste collection system

The residents are to segregate wet and dry waste at source. Wet waste is handled at the household level itself, so only dry waste is to be collected. The households or shops or schools, store dry waste generated, in the blue bags provided to them. Dry waste is collected door to door from all 11 villages of Orohalli, on a weekly basis, by the waste collection personnel, using the Electric vehicle (E-vehicle) provided.

An old Panchayat building in Orohalli was repaired, and is being used as the dry waste storage unit. Dry waste collected using the E-vehicle, is sorted and stored in the Dry Waste Collection Centre (DWCC). Dry waste is sorted into 8-9 categories, by our staff in the DWCC, based on the commercial value in the local scrap market. The remaining dry waste is sent to cement factories, for co-processing, as a partial replacement of coal. The high value recyclables go to the respective recycling facilities through local scrap dealers.


## 6. Dry waste collection data

- Recyclables weighing 1134.5 kg has been sent to recyclers
- Load of 9.72 Tonnes sent to cement kiln for co-processing in the project year of 2017-18
- Revenue of nearly INR 7500 generated through the sale of high value recyclables

| Dry waste in kg | | | | | |
|---|---|---|---|---|---|
| **Month** | **Waste Collected** | **Sent to Cement Kiln** | **Sent to Sorting** | **Sent to Recycler** | **Revenue in Rs** |
| Nov-17 | 1097.5 | 0 | 0 | 30.5 | 204 |
| Dec-17 | 1467.5 | 0 | 0 | 46.5 | 291.5 |
| Jan-18 | 1649 | 1300 | 0 | 0 | 0 |
| Feb-18 | 1571.5 | 2620 | 0 | 270 | 1851 |
| Mar-18 | 1477.5 | 0 | 0 | 122 | 805 |
| Apr-18 | 1476.5 | 2760 | 0 | 195 | 1287 |
| May-18 | 1799.5 | 0 | 0 | 339.5 | 2263 |
| Jun-18 | 1695 | 3040 | 0 | 125.5 | 824 |
| Jul-18 | 2013.5 | 0 | 2350 | 0 | 0 |
| Aug-18 | 2068.5 | 0 | 0 | 5.5 | 0 |
| **Total** | **16316** | **9720** | **2350** | **1134** | **7526.5** |

Collection of dry waste from the villages started in November, after nearly 2 months of awareness and campaigning. Total dry waste collected, during the project period is 16.3 Tons. On an average, nearly 1630 kg of dry waste is collected per month, in the Panchayat area.

## 7. Project Impact

- Clean up drives, Pledgethon to reduce/stop using single use plastics, SwacchaSarvekshan-jaatha, and various other activities conducted to involve volunteers, school children and villagers.
- Awareness on waste has been created among the residents of 11 villages of Orohalli Panchayat.
- Visible improvement in level of cleanliness and cleaner drains in the Panchayat limits.
- Around 10 dumpsites are completely cleared since residents stopped littering and started storing and handing over dry waste to the staff on a weekly basis.
- Conducted awareness sessions on single use plastic usage and encouraged citizens and panchayat members not to use any kind of disposables.
- Continuous community involvement, in order to involve villagers, to sensitize on waste and to make them aware of the health hazards and pollution, due to littering or burning waste.
- Employment has been created for 2 people at the panchayat level
- Significant reduction in the usage of disposables in panchayat office, school and community events.
- Four truckloads of non-recyclable waste have been sent to ACC Cements for co-processing.
- 95% of collected dry waste is either recycled or used as energy source during cement production.
- Nearly 16 Tonnes of dry waste was prevented from littering, open dumping and from being burnt, thus preventing any negative impact on the environment.
- Greenhouse gas emissions amounting to nearly 1120 kg of $CO_2$ gas would have been released, if the above waste had been openly burnt or dumped.

# Development of a locally manufactured Turgo Turbine

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## Background

Nepal has a rapidly growing energy demand (SARI 2018). The geography of Nepal makes it difficult to connect its people by road, let alone supply access to grid electricity (World Bank Group 2016). In 2014, the World Bank estimated that around one third of Nepali people lacked access to any electricity at all (Kumar, et al. 2015).

Whilst over 90% of the urban population may have access to electricity, only 5% of those in rural areas will have such access. This forces many people in rural areas to rely on firewood and animal waste as a source of fuel for their cooking and lighting needs (SARI 2018). Such fuels cause health hazards, especially for women and children who are usually indoors when cooking occurs. It is therefore a priority to introduce clean energy to such rural communities, especially because of the strong link between access to energy and reduction of poverty (SARI 2018).

Over the last twenty years, an increasing number of small, off-grid communities have begun to take advantage of Nepal's mountainous terrain in the form of small, standalone hydropower systems. Nepal has some of the best opportunities for hydropower electrification in the world, however in 2013 it was estimated that only 0.8% of this potential had been utilized (Sovacool, et al. 2013). Political conflict, regular landslides, corruption and seasonal flooding are just a few of the problems faced by hydropower users (Sovacool, et al. 2013).

Another problem is the lack of development and research into new and improved hydropower technologies. Nepal has primarily used Pelton and Crossflow turbines for pico and micro hydropower systems, with manufacturers able to alter the designs to suit the head (height in meters over which water will drop) and flow rates of different sites. These designs have existed for over 100 years without any major design changes (IHA 2018)and alternative options haven't properly been explored in Nepal.

## The Turgo Turbine

Previous research studies have demonstrated that the Turgo turbine can be a good alternative design to Pelton and Crossflow turbines (Benzon, Aggidis and Anagnostopoulos 2015). Invented in 1919, the Turgo turbine is an impulse turbine adapted from the Pelton turbine. The key benefit of a Turgo turbine is that for the same head and flow conditions, a smaller runner is needed than for a Pelton turbine under the same conditions (Benzon, Aggidis and Anagnostopoulos 2015). Another key advantage is that Turgo turbines are traditionally a good choice for sites with head and flow rates in between those for a Pelton or Crossflow turbine (Williamson, Stark and Booker 2011).

Turgo turbines are characterised by robust and reliable performance over a range of head and flow conditions, although they are usually used for medium to high head applications. Despite this, recent research has shown that Turgo turbines can be designed for use at low heads as well (Williamson, Stark and Booker 2012). Turgo turbines are also very good at handling sediment which is important given the high sediment quantity in Himalayan Rivers (Thapa, Shrestha and Dhakal 2005). These qualities make the Turgo Turbine a promising alternative for use in Nepal.

Unlike Pelton turbines, water hits the Turgo runner from above at an inclined angle of 20° and exits from the other side, leading to less interference between incoming and exiting jets of water (see Figure 1). However, one of the key problems with the Turgo turbine is that it remains the least developed amongst established hydropower turbines (Benzon, Aggidis and Anagnostopoulos 2015). There is still much research to be done to improve its efficiency and reduce manufacturing costs. Such research could develop a Turgo turbine that can compete alongside more traditional turbines.

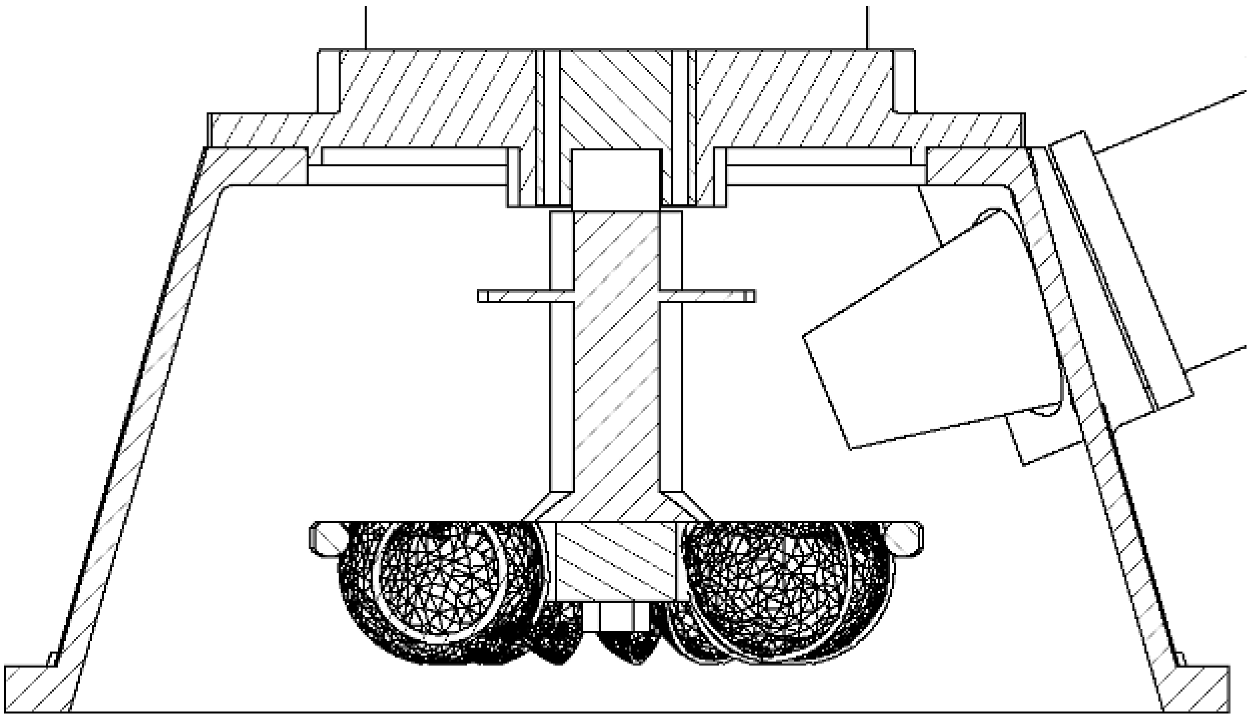

*Figure 1: Cross Section of Turgo Turbine*

## The Turgo Turbine Development Project

A collaborative project between People, Energy and Environment Development Association (PEEDA), Turbine Testing Lab, Kathmandu University (TTL), Nepal Yantra Shala Energy (NYSE) and UoB (the University of Bristol) aims to develop the Turgo Turbine so that it can be locally manufactured in Nepal. This involves the optimised design, development and testing of a new turbine runner which will be compared experimentally to an imported design. The new pilot Turgo turbine will then be installed in a pilot site in Nepal, and then monitored and evaluated. The desired outcome of this project is a design package of a Turgo Turbine that a Nepali manufacturer could adapt to a range of flow and head specifications.

Additionally, the project aims to understand and investigate the potential for Turgo turbines in the current hydropower market, by undertaking an analysis of existing technologies, methods of manufacture, and a cost analysis. Several academic papers should also result from this project.

## Design Work

The technical design work is being performed by researchers at the University of Bristol. The main design work revolves around the optimisation of the turbine runner, which is the part of the turbine that rotates due to the force of the water. A reference, digital model was created from an imported turbine using Computer Aided Design (CAD) software.

One of the key challenges is to create a digital, parametrized version of the turbine runner cup. This means the creation of a cup that can be 'edited' – a cup with changeable geometry. The reason this is difficult is because the cup has non-uniform curvature, so there are lots of ways that the geometry can be changed.

Another key challenge is testing the digital cup using Computational Fluid Dynamics (CFD) software. This is how researchers model the effects of fluids like water interacting with solid bodies, like the Turgo cup. Because of the curvature of the cup, the interaction between a jet of water and the runner cup is complex to model (See Figure 2).

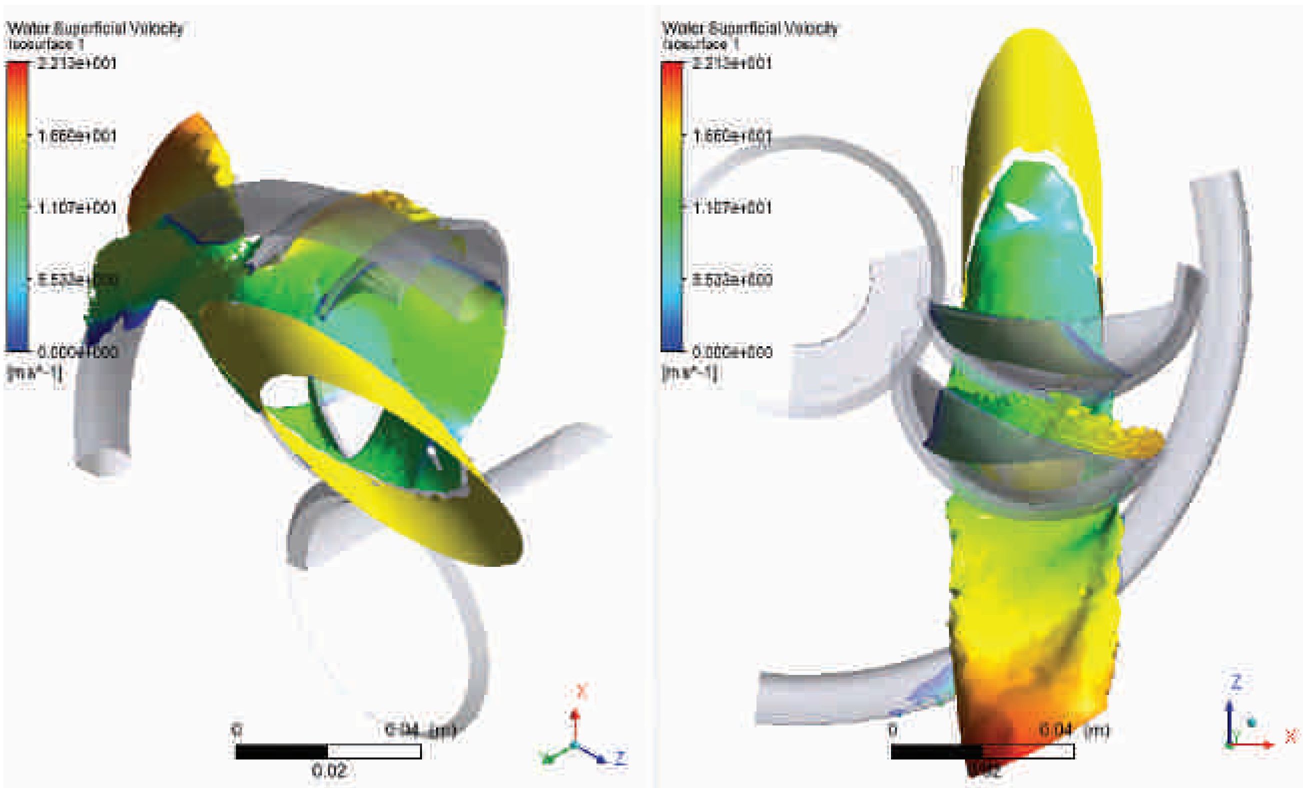


*Figure 2: CFD model of Turgo Turbine*

After the creation of a CFD model, the accuracy of the model will be assessed against experimental data collected by testing the imported turbine at the Turbine Testing Lab in Kathmandu University. If the data is very different from the CFD model's prediction, researchers will know that the model is inaccurate. After relevant changes to the digital model, various geometries can be compared, and a new runner design can be created. This will also be tested in the Turbine Testing Lab, to experimentally assess its performance.The new pilot turbine will be further assessed after installation into a pilot site. Evaluation and monitoring of this pilot turbine will give indication of its long-term performance, and any necessary operation and maintenance that will be needed. Hopefully, this project will develop the Turgo turbine further and make a start towards diversifying the micro hydro options available in Nepal.

## References

Benzon, D. S., G. A. Aggidis, and J. S. Anagnostopoulos. 2015. “Development of the Turgo Impulse turbine: Past and present.” (Applied Energy) 2016.

IHA. 2018. A brief history of hydropower. Accessed November 2018. https://www.hydropower.org/a-brief-history-of-hydropower.

Kumar, Priti, Tomoyuki Yamashita, Ajoy Karki, S C Rajshekar, Ashish Shresth, and Abhishek Yadav. 2015. “Nepal - Scaling up electricity access through mini and micro hydropower applications : a strategic stock-taking and developing a future roadmap (English).” www.worldbank.org. Accessed November 2018. http://documents.worldbank.org/curated/en/650931468288599171/Nepal-Scaling-up-electricity-access-through-mini-and-micro-hydropower-applications-a-strategic-stock-taking-and-developing-a-future-roadmap.

SARI. 2018. Nepal: South Asia Regional Initiative for Energy Integration. Accessed November 2018. https://sari-energy.org/oldsite/PageFiles/Countries/Nepal_Energy_detail.html.

Sovacool, Benjamin K., Saroj Dhakal, Olivia Gippner, and Malavika Jain Bambawale. 2013. “Peeling the Energy Pickle: Expert Perceptions on Overcoming Nepal’s Energy Crisis.” South Asia: Journal of South Asian Studies.

Thapa, B, R Shrestha, and P Dhakal. 2005. “Problems of Nepalese hydropower projects due to suspended sediments.” Aquatic Ecosystem Health and Management.

Williamson, S J, B H Stark, and J D Booker. 2011. “Low head pico hydro turbine selection using a multi-criteria analysis.” Renewable Energy.

Williamson, Sam J., B. H. Stark, and J. D. Booker. 2012. “Performance of a low-head pico-hydro Turgo turbine.”

World Bank Group. 2016. Strengthening rural connectivity in Nepal. Accessed November 2018. http://www.worldbank.org/en/news/feature/2016/02/17/strengthening-rural-connectivity-in-nepal.

# Solar Powered Cold Storage and Potential Issues

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Refrigeration plays an important role in the preservation of perishable foods. Many rural areas of the world produce ample food supplies but there are considerable losses due to lack of preservation facilities. In most places where there is no electricity, the concept of solar refrigeration seems attractive because of rough coincidence of energy supply and cooling demand(Exell et al., 1987). People, Energy and Environment Development Association (PEEDA) has recently installed a solar powered cold storage unit in Baiteshwor Rural Municipality. This article outlines pre-installation considerations and potential issues that may arise during installation of a solar powered cold storage unit and the need for these issues to be addressed thoroughly.

## 1. Pre- installation considerations

Early site evaluation leads to better system design with benefits of increased energy production and better quantification of size requirement. The parameters are discussed below:

### 1.1 Land Orientation

The measurement of location parameters such as the available area for the array, roof pitch and azimuth are necessary. Solar panels must be facing true south and not magnetic south, as normally shown by a compass in the northern hemisphere. This ensures absorption of maximum solar energy over the course of the entire year. The magnetic declination of the site can be done to see deviation from true south. Google Earth is a handy tool to check this.  Land property that can satisfy this orientation is preferred.

Sometimes the orientation of the property or roof doesn't permit for an exact south facing. One solution is to compensate by increasing the solar collector area, either by using more panels or larger collectors. Mounting the panels on racks that orient them to face south is possible, although this will be more expensive than a standard installation.

But according to a new study done by Pecan Street Research Institute (Exell, Bhattacharya, & Upadhyaya, 1987), solar panels actually do better when pointed west because peak demand on the power grid is in the afternoon and evening, and so getting more solar power during that period is actually more useful at reducing the need for polluting sources of energy.

The Pecan Street Research Institute study shows that west-facing panels, compared to south-facing ones, produce 49% more electricity during peak demand time.

## 1.2 Solar Irradiation

In general, solar irradiation is the input for all solar energy generating systems, typically expressed in $kWh/m^2/day$. The amount of solar radiation available over time under local environmental conditions helps to choose the suitable location and size of a solar energy project. Additionally, high precision on site solar radiation measurement gives the lowest uncertainty about the energy resources and the possible energy yield. Such measurement provides energy forecast and site prospects to bring maximum return from the project (Kipp & Zonen, n.d.).

## 1.3 Seasonal impact on solar output

Azimuth angle and tilt angle are important parameters which determine the output from solar panels. PV arrays are most efficient when they are perpendicular to the sun's rays. However, throughout the year the sun's path and the solar altitude vary. In summers, the sun is high in the sky whereas in winters it is lower (Suman, 2015). These parameter are dependent on the site itself.

Increasing the tilt angle favors energy production in the winter, while decreasing the tilt angle favors energy production in the summer. If a standalone system is to be used, either the best tilt angle must be chosen for a fixed frame or fixtures to support changeable tilt angle must also be installed. Change of tilt angle by 14 degrees in the month of June would increase the energy production by 11% (Suman, 2015) .

## 1.4 Shading on the solar panels

Partial shading is the condition when the modules connected in series and parallel don't receive the same illumination compared to the other modules and results in uneven power generation by the different modules of the same rating. If the same power doesn't flow to all the modules then the lower generating modules will act as a sink and absorb the power from the modules which are generating more power, and the result would be dense power loss. Because of the absorption of the power, the cells heat up and cause hot spot problems, which could result into the cracking of the glass shield.

*Figure 1 : Solar site analysis using solar path finder, Photos : Author*

Most modules are manufactured with built-in bypass diodes that can help mitigate the effects of partial shading, but even a shaded row of cells can disable the module. Thus, careful site planning and design considerations are needed to reduce the impact of shading.

Predicting shading throughout the year from various obstructions—such as tall trees, nearby buildings, roof dormers, and even chimneys—can be challenging if done by sight alone, requiring many observations over the course of the year. But several tools, including the Solar Pathfinder, the Acme Solar Site Evaluation Tool, and the SunEye, can quickly help to assess shading on the site throughout the year—with one site visit.

## 1.5 Presence of animal shelter and grazing area

Any kind of animal shelter or grazing area close to the cold storage location will result in pest infestation. This will enhance tiny bacterial particles entering inside the cold storage infrastructure thereby infecting the stored vegetables. Thus, it is better to select a site with no animal shelters nearby or to remove any such areas before installation. Grazing control requires a barbed wire fence around the property.

## 1.6 Proximity of the site with the community and roads

Centralized installation of cold storage will ensure ease of access to the community. The importance of site readiness should be given higher priority. Solar powered cold storage contains very bulky items that require proper care and consideration during the pre-installation period to ensure that the intended installation site is located within carrying distance.

## 1.7 Required based design

Solar cold storage systems require 3 phase grid connection for smoother run of the motors and more instantaneous power. 3 phase comes with higher cost for connection. Compatible compressors and fans need to be selected. If local machine workshops don't have confidence repairing 3 phase motors then confusion might occur. For a remote context, a single phase system is cheaper and easier. Usually if the load is less than 20A then single phase system must be considered.

Identification of different crop seasons is wise as well it can determine the size requirement of a cold storage unit. However, production estimates in heterogeneous smallholderfarming systemsoften rely on labor-intensive surveys that are not easily scalable, nor exhaustive. Recent advances in high-resolution earth observation (EO) open up new possibilities to work in heterogeneous smallholder systems. Results from a study of such estimation in Mali's cotton belt shows that crop types can be mapped from Sentinel-2 data with 80% overall accuracy (OA) (Lambert, Traoré, Blaes, Baret, & Defourny, 2018). These estimations would ensure optimum volume as well as power requirement selection of the system.

## 1.8 Dedication of the Management Committee

Remote locations are always preferred because of their capacity of transforming organizations and redefining social relationships. However, remoteness also increases the difficulty of monitoring and maintaining the system. A management committee should be established which chooses the operator, encourages production and storage, handles, labels, transports and sells the stored produce, and schedules maintenance and managing in every way necessary for the success of the system. A large amount of time and dedication is required by every individual of such a committee for its daily operation. However, initially the system may not generate revenue and so the committee members can be reluctant to show up. Challenges and risks arise sourcing local expertise capable of handling the roles of a management committee.

## 1.9. New Technology Penetration

A study conducted in rural Malaysia shows that attitude, perceived ease of use and perceived usefulness have a positive and significant relationship with acceptance of any new technology (Samah, Shaffril, Hassan, & D'Silva, 2011). Door to door interviews and counselling can combat these challenges if the coverage area is small. Monetary benefit that can be provided by the system must be estimated. Perception of usefulness when developed in people will ultimately lead to change in their attitude towards a revolutionary system.

New technology of solar storage brings with it the difficulty for breakdown and corrective maintenance. A local operator must be readily available to handle breakdowns with his skills and time. Diagnosis of solar cold storage might not be possible by the local level of knowledge. For this, a technical training and exposure visit should be provided. The company that installs the system might not always be available to provide its services. Thus, to sustain the system even after the warranty period, a base level operator and secondary level electrician must be selected. This labor availability search in a rural locality is often a tedious job. Collaboration from local government, private sector and community based organization is necessary.

## Conclusion

To conclude, solar powered cold storage is a unique system of its own in Nepal promoting the use of renewable energy. However, the uniqueness of the system is a challenge for everyone in terms of sustainability. The above-mentioned points are few of the unseen issues that need to be dealt in a careful manner. Proper care, attention for these issues will enhance the life span of the system thereby improving the shelf life of vegetables which in turn improves rural livelihoods. Such systems should be prioritized by relevant stakeholders where renewable energy is promoted thereby benefiting rural communities by use of environment friendly technology.

## References

Exell, R., Bhattacharya, S., & Upadhyaya, Y. (1987). Solar Cooling for Cold-Storage Applications Using Solid Desiccants and Adsorbents Physics and Technology of Solar Energy (pp. 405-411): Springer.

Kipp & Zonen. Solar Irradiance Monitoring in Solar Energy Projects. Netherland: Kipp & Zonen.

Lambert, M.-J., Traoré, P. C. S., Blaes, X., Baret, P., & Defourny, P. (2018). Estimating smallholder crops production at village level from Sentinel-2 time series in Mali's cotton belt. Remote Sensing of Environment, 216, 647-657.

Samah, B. A., Shaffril, H. A. M., Hassan, M. A., & D'Silva, J. L. (2011). Can technology acceptance model be applied on the rural setting: The case of village development and security committee in Malaysia. Journal of Social Sciences, 7(2), 113.

# Plastic tunnel farming:
# A coping strategy from climate change

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## Introduction:

Rural areas of Nepal where the community mainly depends on agriculture are the most vulnerable to extreme climate events such as high temperatures in summer, excessive rainfall in monsoon season and cold temperatures in winter months. This affects vegetable cultivations like tomato, onion, cauliflower etc. Protection of vegetables from extreme climates is a priority to meet the rural households' requirements mainly in the mid-hills of Nepal. Tunnel farming is a simple and low cost practice against adverse weather conditions, which helps the farmers to grow off-season vegetables and secure food supplies throughout the year as well as improving their earning through high demand vegetables such as tomatoes (FAO,2008).

## Plastic tunnel farming:

The practice of off-season vegetable farming in the mid-hills using plastic tunnel growing gradually, which is focused to terai market during wet season (June-October). The major attractionsof this technology isits low cost, that it can be used for a small area of land and that it provides a better income compared with traditional crops farmed using conventional methods. For instance, by growing high demand vegetables such as tomatoes over 100 $m^2$ area, as much as USD 350-500 can be earned over the short time period from June to November.(ICIMOD, 2013)

Playhouse (See figure 1) requires plentiful sunshine with no shade throughout the growing season and the surrounding area must be well-drained. Locally available bamboo can be used to make a frame earlier in the year; however the plastic roofing can be added after few rainfall events. The altitude determines the height of the polyhouse. For instance, for higher elevations, the height of the polyhouses are lower to retain high temperature and humidity, while the height of the  polyhouses are higher at lower elevations to allow breeze to circulate and humidity to dissipate. (ICIMOD, 2013)

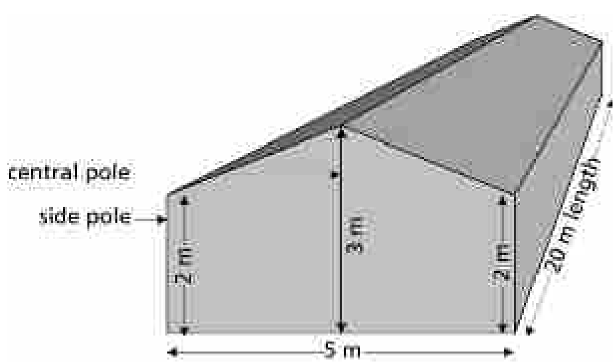


*Figure 1: Sketch of a polyhouse. The optimum length is 20 m and the width 5 m. The height of the central and side poles varies depending on the elevation. Note that there should be a space of at least 1 m between polyhouses. (ICIMOD, 2013)*

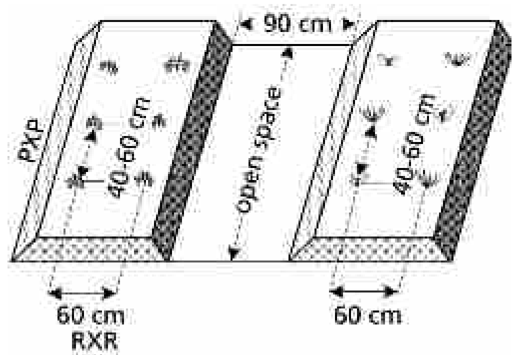


*Figure 2: Cross sectional view of a planting bed showing row-to-row (RXR) and plant-to-plant (PXP) distances. There should be a space of at least 90 cm between beds. Note that this is for tomato which may varies for other vegetables. (ICIMOD, 2013)*

## Experience of PEEDA supporting plastic tunnel use

It is a well-known fact that climate change results in irregularities in the natural ecosystem which reduce agricultural productivity. PEEDA's climate assessment of selected wards within the Dolakharegion revealed high variability in precipitation. The community observation across the wards noted increased incidences of heavy rainfall in a short time and longer gaps between successive rainfalls. As the majority of the farmers in the given area are dependent only upon seasonal farming, drought during the main plantation season decreases productivity. In addition, unanticipated heavy rainfall leaves most agro production in disarray. Ultimately, they cannot grow enough food and vegetables to support their families and are left with no other option than taking loans from local money lenders at very high interest rates.

Support for agriculture practices to develop adoptive capacity is needed to prepare for drastic impending climate change (FAO, 2008). PEEDA undertook a project in Dolakha to combat the foreseeable effects of climate change within the region. As part of this project, PEEDA promoted plastic tunnel farming in the area, so that they can make better use of their land and reduce the negative effects of climate variability.The organization provided seeds and plastic tunnel as well as training to 100 farmers. The latest monitoring and evaluation report demonstrated that the use of land for vegetable production has increased by 30% whilst generating an income of NPR 15000 to 20000(on average/per season). This income was mostly used for household purposes as well as to purchase wider varieties of seeds so that farmers can continue to improve their earnings.

## Conclusion:

The immediate income generated per plastic tunnel in the beginning may not have good return, however farmers are hopeful to generate sustainable return in future by adopting resilient farming methods against climate change.

## References:

ICIMOD, 2013. Natural Resource Management Approaches and Technologies in Nepal:

Technology –A low-cost polyhouse for tomato production in the rainy season

FAO, 2008. Climate change adaptation and mitigation: challenge and opportunity for food security.

# Landslides in Dolakha district, Nepal and effects on Micro-Hydropower

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## Introduction

The Himalayan range including Nepal is exposed to various geohazards, amongst them landslides (Owen 2018). Nepal and especially its mid-hills including the Dolakha district are high-risk landslide areas (Sudmeier-Rieux et al. 2012; Fig. 1). Complex interactions of various factors amongst them high rainfalls and seismic activity trigger these landslides with potentially disastrous consequences as shown by Nepal's 2015 Gorkha and Dolakha earthquakes (Kargel et al 2016, Roback 2018).

High amounts of monsoon rainfall are concentrated in Nepal during a short period from June to August, known as the rainy or monsoon season. Approximately 80% of the annual precipitation sum accumulates during this time and precipitation extremes are rising across Nepal in the course of climate change. Mean annual rainfall ranges between 1.5 mm and 2.5 mm. Earthquakes are another reason for landslides. The Himalayan range is located at a plate boundary, where the Indian and Eurasian plates are colliding. The plates are moving fast against each other leading to stress corrosion. The hilly areas are prone to landslides because of the weak and often highly weathered geological structure, frequent tectonic uplifts and by precipitation amplified erosion of slopes (Karki et al. 2016, Karki et al. 2017, Raut and Gudmestad 2018).

Micro-Hydropower is one of the main sources of energy generation in Nepal. Nepal's climate, topography and sloping hills provide good opportunities for developing hydropower plants (Raut and Gudmestad 2018).

The objective of this report is to understand which places in the Dolakha region might be threatened to a high degree by landslides. We present an overview on landslide-triggering factors and approaches of landslide protection and prevention. Moreover, we discuss the potential susceptibility of micro-hydropower plants to landslides. To obtain the objective we combine condensed outcomes from a literature review and impressions and preliminary results from an explorative field trip to the study area in September 2018.

## Landslide triggering factors

Landslides are defined as the gravitational mass movement of rocks, debris, or earth down a slope. Landslides are complex systems, which have many different factors causing the mass fails. To classify landslides, they are separated by material properties and process types. Another classification of landslides is based on movement velocity.

The most frequent types of earth movements are earth slides, earth flows, debris slides or debris flows. They all belong to the type of faster landslides with speeds ranging from extremely rapid >5 m/sec to rapid >1.8 m/h (Thiebes 2012).

Landslides are a sign of slope instability. Out of several geological factors, steep slope controls mainly the ground acceleration i.e., by earthquakes triggered landslide activity. In addition, soil cover, texture and water capacity are main factors. Vegetation protects the soil from erosion. Consequently, it is important how vegetated the area is and how much water the soil can absorb. These factors interact: The roots of the plants stabilize the soil until it saturated with water i.e., cannot absorb it anymore. In consequence, the slope starts to move downward. Another important factor is angle of the slope. The downslope force increases the steeper the slope is (Thiebes 2012, Kargel et al. 2016, Martha et al. 2016).

The most common natural triggers of landslides are related to geological events, such as seismic shaking i.e., earthquakes. Hydrological events, amongst them intense rainfalls, rapid snow melts or water level changes in rivers or lakes at the foot of the slope cause landslides as well. Moreover, human interaction in form of loading by e.g., buildings or slope cutting can trigger these mass movements (Thiebes 2012).

In Dolakha, landslides occur mostly during the monsoon season because of the high precipitation during this period. The shallow and sandy soils can only absorb a limited amount of water. If the rain delivers high amounts of water the risk for the ground starting to move increases. The initial points of landslides are often located where a road was built recently because the water accumulates here and can't drain off. In addition, road construction destabilized the soil and bedrock and initiates cracks and detachment of soil and bedrock layers.

## Challenges of landslide prevention

In general, there are two different approaches to landslide prevention and hazard avoidance. One is an early warning system. Sensors of early warning systems for landslides are placed in the ground. They monitor the ground's stability and signal if the soil starts to move. When this happens, they will send a signal to other stations and finally to experts and local population. But there are many potential problems with this kind of system. People have to be trained so that they know how the system works. The early warning systems have to be checked often to function properly and to warn people in case of a landslide. In addition these systems are expensive and thus less useable for developing countries such as Nepal (Thiebes 2012).

The second landslide protection approach is bioengineering which, like warning systems, is a prevention method as such. Soil and vegetation are the fundamental parts for bioengineering techniques. The soil stability is driven by mechanical and hydrological properties of plants. The mechanical component comprises the plant roots which increase the shear strength of the soil. This happens because of the network-like root structure which binds and anchors the soil. Three main mechanical properties are attributed to roots: These are (1) anchoring, (2) providing lateral support by crossing zones of weakness and (3) acting as widespread, spatially extended fibrous binders within a weak soil mass (He et al. 2017, Raut and Gudmestad 2018).

The hydrological functions include various processes such as interception, precipitation, evaporation, water storage, leaf drip, pool formation, water uptake, transpiration and infiltration. Most importantly for landslide protection, the hydrological processes imply removing water from the soil by evapotranspiration through the vegetation. Evapotranspiration reduces the moisture content as well as the weight of the soil mass. Overall the properties of the plant roots have a positive influence on maintaining the slope stability (Raut and Gudmestad 2018).

In addition, vegetation cover protects the soil from one of the initial parts of the erosion process for example, particle dispersion ("splashing") caused by the kinetic energy of raindrops hitting the ground surface. Leaves slow down the speed of raindrops and reduce their kinetic energy by leaf drip. In consequence, a high percentage of ground covered by vegetation contributes significantly to soil erosion protection. Land use practices influence the vegetation cover. For instance, vegetation can cover a higher percentage of soil in agroforestry systems in comparison to monocropping dominated land use practices as shown by Schick et al (2018) for a site in the mid-hills of Nepal. Community forestry programs improve hazard protection as well (Martin and Sauerborn 2013, Niraula et al. 2013, Blume et al. 2016).

Both approaches of landslide prevention are difficult to deploy in Dolakha without further, more detailed investigations. More or less natural areas e.g., forested parts, are highly vegetated and comprise often a scrubby understory ("jungle"). Afforestation or other bioengineering techniques seem to be of minor use at these sites since there is already a dense vegetation cover and high root density. However, agricultural land, settlements, roads and other anthropogenic influenced land might be exposed to landslide risk of varying degrees. Early warning systems might be difficult to install at sites with dense vegetation and their cost-benefit ratio is questionable. In order to find out which regions are at higher or lower landslide risk, we recommend to develop a risk map. We aim to include all information that we collected in the field at recent landslide sites (bed rock, soil texture, slope, size of landslides, vegetation cover, land use) and combine this data with freely available remotely sensed data (history of land use, soil moisture, various relief parameters). The application of the STEP TRAMM landslide triggering model (von Ruette et al. 2011, Fan et al. 2017)will support this approach. The resulting maps will help to understand which sites are risky for the construction of new houses and roads and where an adaptation of land use practices might support the reduction of the landslide risk.

Education reduces disaster vulnerability significantly (K.C. 2013). Thus local knowledge of landslide prevention could be collected and disseminated e.g., by skills training on landslide mitigation which can be incorporated in agricultural outreach or community forest user group training or meetings of relevant stakeholders (Sudmeier-Rieux et al. 2012).

## Problems with hydropower systems and landslides

The development of a hydropower systems is a challenging task due to the complex terrain in Nepal and the requirement to avoid landslides. On the one hand hydropower systems can be damaged by landslides; on the other hand, the construction work itself can trigger gravitational mass movements. The major impacts of landslides on hydropower systems are damage or complete destruction of transmission lines and their poles or other parts of the power plants such as penstock, headwork, anchor blocks and powerhouse (Raut and Gudmestad 2018).Rebuilding or replacing parts of a hydropower system is time, labor and cost intensive. A better knowledge on landslide triggering factors and on prevention measures would reduce repair effort and costs.

## Conclusion

Landslides are defined as a gravitational movement of mass down slopes. They often happen during extreme nature events such as precipitation extremes or earthquakes. Active landslides have a heavy destructive influence on cultivated land, hydropower systems as well as on other human infrastructure such as buildings and roads. The prevention of landslides is complex because of the many different factors which have an influence on their occurrence as triggering factors for example, soil, slope, vegetation and destabilizing actions on the slopes by humans. These natural and anthropogenic interventions are at every location different and can dangerous for people.

For this reason, we recommend that PEEDA aims to build a better understanding of landslides by including local knowledge, educating the local population and planning site-specific bioengineering-based protection measures which can be implemented to protect certain areas. As a result, the local population and project investments of PEEDA will be better protected and more resilient and sustainable.

*Figure 1: Landslides in the Dolakha region (T. Brecht 09/2018).*

## References


Blume H-P, Brümmer GW, Fleige H, Horn R, Kandeler E, Kögel-Knabner I, Kretzschmar R, Stahr K, Wilke B-M (2016) Soil science. Springer, Berlin, Germany

Fan L, Lehmann P, Or D (2017) Load redistribution rules for progressive failure in shallow landslides: Threshold mechanical models. Geophysical Research Letters 44:228–235. doi: 10.1002/2016GL071763

He S, Wang D, Fang Y, Lan H (2017) Guidelines for integrating ecological and biological engineering technologies for control of severe erosion in mountainous areas – A case study of the Xiaojiang River Basin, China. International Soil and Water Conservation Research 5:335–344. doi: 10.1016/j.iswcr.2017.05.001

Kargel JS, Leonard GJ, Shugar DH, Haritashya UK, Bevington A, Fielding EJ, Fujita K, Geertsema M, Miles ES, Steiner J, Anderson E, Bajracharya S, Bawden GW, Breashears DF, Byers A, Collins B, Dhital MR, Donnellan A, Evans TL, Geai ML, Glasscoe MT, Green D, Gurung DR, Heijenk R, Hilborn A, Hudnut K, Huyck C, Immerzeel WW, Liming J, Jibson R, Kääb A, Khanal NR, Kirschbaum D, Kraaijenbrink PDA, Lamsal D, Shiyin L, Mingyang L, McKinney D, Nahirnick NK, Zhuotong N, Ojha S, Olsenholler J, Painter TH, Pleasants M, Pratima KC, Yuan QI, Raup BH, Regmi D, Rounce DR, Sakai A, Donghui S, Shea JM, Shrestha AB, Shukla A, Stumm D, Kooij M van der, Voss K, Xin W, Weihs B, Wolfe D, Lizong W, Xiaojun Y, Yoder MR, Young N (2016) Geomorphic and geologic controls of geohazards induced by Nepal's 2015 Gorkha earthquake. Science 351:aac8353. doi: 10.1126/science.aac8353

Karki R, Talchabhadel R, Aalto J, Baidya SK (2016) New climatic classification of Nepal. Theor Appl Climatol 125:799–808. doi: 10.1007/s00704-015-1549-0

Karki R, Hasson S ul, Schickhoff U, Scholten T, Böhner J (2017) Rising precipitation extremes across Nepal. Climate 5:4 .doi: 10.3390/cli5010004

K.C. S (2013) Community Vulnerability to Floods and Landslides in Nepal. Ecology and Society 18:8. doi: 10.5751/ES-05095-180108

Martha TR, Roy P, Mazumdar R, Govindharaj KB, Kumar KV (2017) Spatial characteristics of landslides triggered by the 2015 Mw 7.8 (Gorkha) and Mw 7.3 (Dolakha) earthquakes in Nepal. Landslides 14:697–704. doi: 10.1007/s10346-016-0763-x

Martin K, Sauerborn J (2013) Agroecology. Springer, Dordrecht, Netherlands

Niraula RR, Gilani H, Pokharel BK, Qamer FM (2013) Measuring impacts of community forestry program through repeat photography and satellite remote sensing in the Dolakha district of Nepal. Journal of Environmental Management 126:20–29. doi: 10.1016/j.jenvman.2013.04.006

Owen LA (2018) Earth surface processes and landscape evolution in the Himalaya: a framework for sustainable development and geohazard mitigation. Geological Society, London, Special Publications 462:169–188. doi: 10.1144/SP462.9

Roback K, Clark MK, West AJ, Zekkos D, Li G, Gallen SF, Chamlagain D, Godt JW (2018) The size, distribution, and mobility of landslides caused by the 2015 Mw7.8 Gorkha earthquake, Nepal. Geomorphology 301:121–138. doi: 10.1016/j.geomorph.2017.01.030

Raut R, Gudmestad O (2018) Use of bioengineering techniques to prevent landslides in Nepal for hydropower development. International Journal of Design & Nature and Ecodynamics 12:418–427. doi: 10.2495/DNE-V12-N4-418-427

Schick A, Wieners E, Schwab N, Schickhoff U (2018) Sustainable Disaster Risk Reduction in Mountain Agriculture: Agroforestry Experiences in Kaule, Mid-Hills of Nepal. In: Mal S., Singh R., Huggel C. (eds) Climate Change, Extreme Events and Disaster Risk Reduction. Sustainable Development Goals Series. Springer, Cham Switzerland, pp 249–264

Sudmeier-Rieux K, Jaquet S, Derron M-H, Jaboyedoff M, Devkota S (2012) A case study of coping strategies and landslides in two villages of Central-Eastern Nepal. Applied Geography 32:680–690. doi: 10.1016/j.apgeog.2011.07.005

Thiebes, B. (2012) Landslide Analysis and Early Warning Systems: Local and Regional Case Study in the Swabian Alb, Germany. Springer, Berlin Heidelberg, Germany. doi: 10.1007/978-3-642-27526-5

von Ruette J, Papritz A, Lehmann P, Rickli C, Or D (2011) Spatial statistical modeling of shallow landslides—Validating predictions for different landslide inventories and rainfall events. Geomorphology 133:11–22. doi: 10.1016/j.geomorph.2011.06.010

# PEEDA AT A GLANCE

PEEDA is an NGO dedicated to improving 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 projects 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 PEEDA is that the poor of Nepal, who live mainly in rural areas, should share the benefits of Nepal's renewable energy resources, but this will not happen without dedicated and sustained effort. For the last two decades PEEDA has striven to empower individuals and communities to help themselves without discrimination whilst maintaining a good relationship.

## News and Events

### Field Observation

The Executive Committee members visited field offices of PEEDA at Namdu and Mirge. Likewise, the EC members also visited some of the vegetable production plots and beneficiaries at Baiteshwor Rural Municipality, ward no. 3 of Dolakha district (former Mirge VDC).

*Figure: Executive Committee members field observation at Baiteshwor Rural Municipality, Ward No.: 3 (Former Mirge VDC)*

## Training on Plastic Tunnel Farming

PEEDA conducted a one-day tunnel preparation training at 4 different farmers groups on 27th, 28th& 31st October and 3rd November 2018 at Jungu, Mirge and Namdu villages of Dolakha district. Tunnel farming is a simple and low-cost practice against adverse weather conditions which helps farmers to grow off-season vegetables and secure food supplies throughout the year as well as improving their earnings through high demand vegetables such as tomatoes. 34 farmers benefited from the tunnel farming training of which 67% were female farmers.

*Figure: Plastic tunnel farming*

## Climate Change and Sustainable Livelihood Workshop

PEEDA has successfully conducted a workshop on Climate Change and Sustainable Livelihood in 4 VDCs of the Dolakha district. The project activities were carried out in Mirge, Namdu, Jungu and Thulopatal VDCs from 25th October to 1st November 2018. One of the main objectives of the workshop was to prepare the Local Adaptation Plan of Action (LAPA). Of the 124 participants, 88 were women.

*Figure: LAPA workshop at Dolakha district*

## Training on Wind Turbine manufacturing

PEEDA and Kathmandu Alternative Power & Energy Group (KAPEG) in collaboration with National Technical University of Athens (NTUA) has successfully conducted a 5-day Small Wind Turbine Construction Course, which was held from 31st October to 4th November 2017.

*Figure: Participating engineering students with instructors*

## Experience sharing at Rural Energy Access: A Global Challenge by PEEDA CEO

The CEO of PEEDA attended the *Global Challenge Symposium* which was held on $12^{th}$ April 2018 as an invited guest to discuss on the issues of Energy and Sustainable Development Goals (SDGs) within Nepal. This session was led by Dr. Sam Williamson, held in Bristol (UK) and co-organized by the University of Bristol's Cabot Institute for the Environment.


*Figure: Mr. Biraj Gautam (CEO) Participating at Global Challenge Symposium*

## Disclaimer Notice

The views and findings expressed in this publication are solely those of the individual author(s) and not necessarily attributable to PEEDA.



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Published by:
PEEDA (People, Energy and Environment Development Association)
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