Energy, Environment and Ecosystems (3E) Nexus towards Building Resilient Societies and Implications to Sustainable Development Goals in Asia-Pacific Region

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Research Initiative for Use of Low Flowing River Resources by Developing New Water Vortex Turbine to address Climate Change

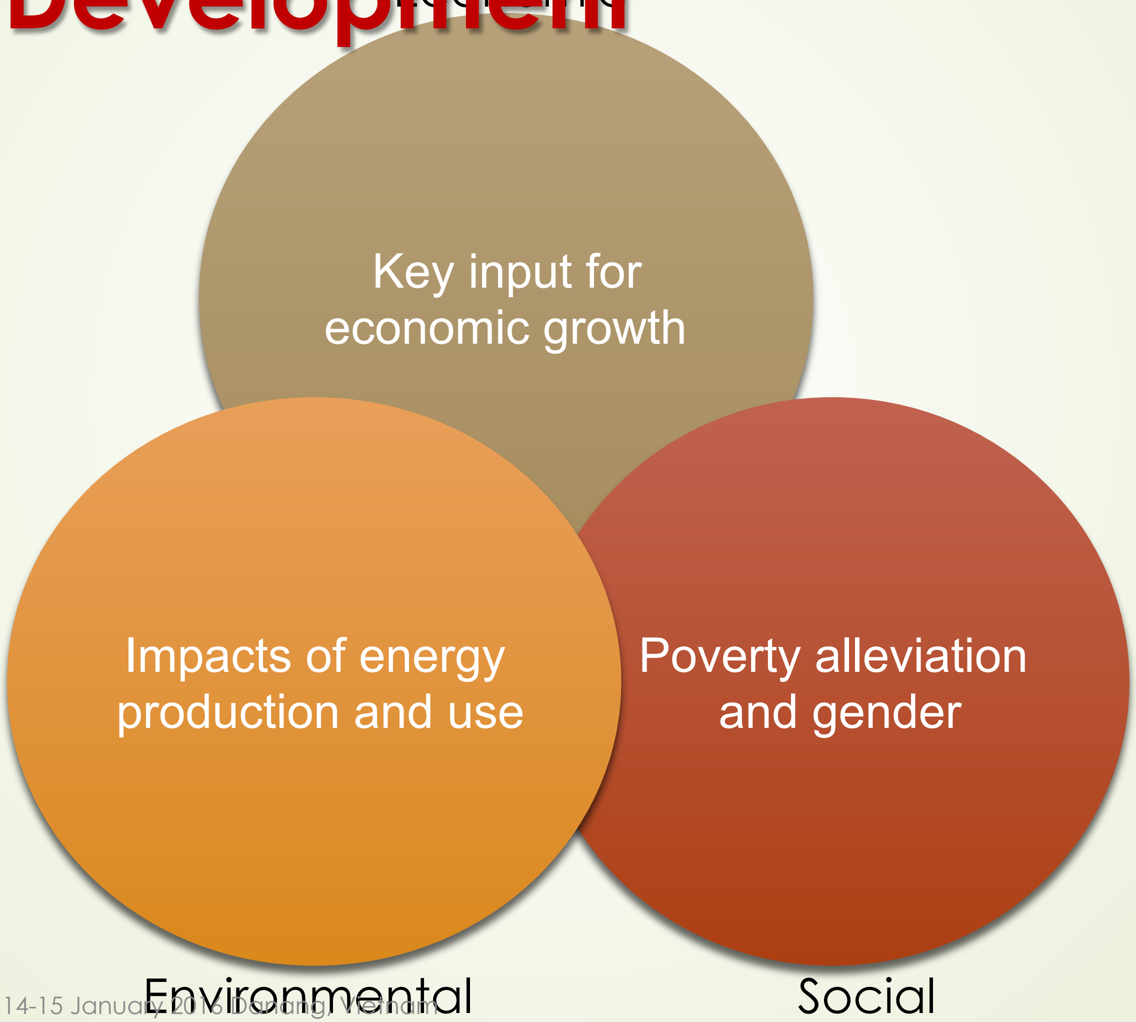
Tri Ratna Bajracharya

Institute of Engineering

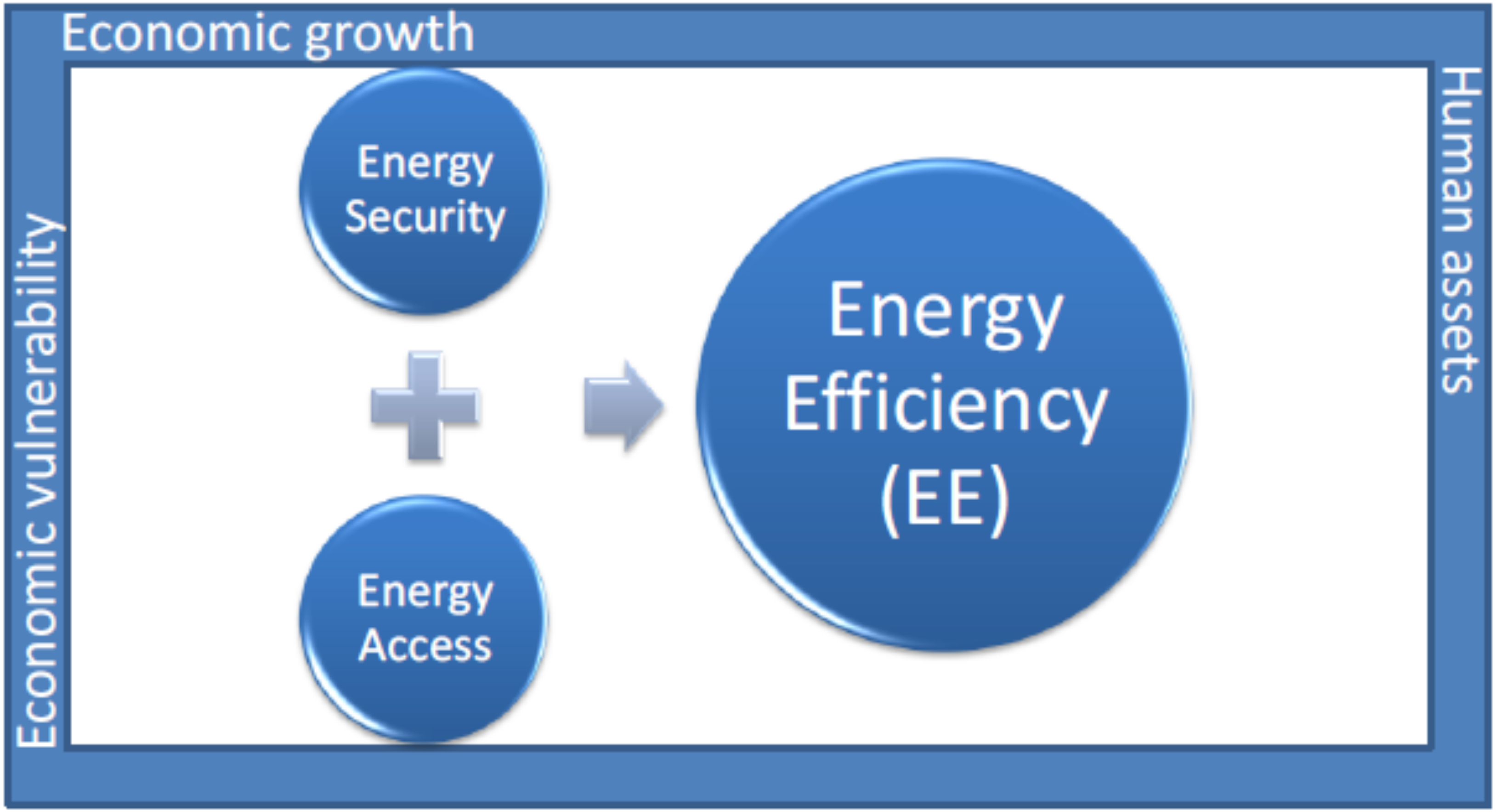
Tribhuvan University

Nepal

Energy for Sustainable Development



Graduating up from Least Developing Countries to Developing by 2022



Nepal's Energy Scenario

- **Present Status of Energy**
  - Hydro :
  - Operating Installed capacity–900 MW
  - Government of Nepal Owned- 478MW
  - Thermal:
  - Installed Capacity – 53MW
    (Owned by Nepal Government)
  - Solar:
  - 200 kW (2 x 100)
- Hydropower constitutes major source of Electrical Energy, 92.14%

Compiled from various sources

Major Rivers of Nepal

Installed Major Hydroelectric Project of Nepal

- Installed Major Hydroelectric Power 900 MW
- Under construction 1050 MW
- Planned 2177 MW
- Total Hydro Potential 83000 MW

Nepal Electricity Authority, 2017

Micro and Pico Hydro : Major Electrifiers of Rural Nepal

- As the name says, "micro" power plant which produces electricity through a water stream. It produces 1 kW to 100 kW power, providing many houses with enough electricity for light and other use.
- "Pico" means " very small", thus speaking of an electricity power production of 200 Watt to 5 kW through a water stream
  - Using Modern LED's can we guess how many houses can you provide with light with such a small power….well its huge
  - The Pico Power Plant is small, uses ready available parts and thus is comparably cheap.
  - Transport, installation and maintenance costs are low and the technologies used simple.
  - This all makes it far more appropriate for undeveloped and remote areas
- What for Flat belts of Nepal?
  - Well a low head pico hydro might be economically most appropriate solution.

Reviewing Operation of Hydropower

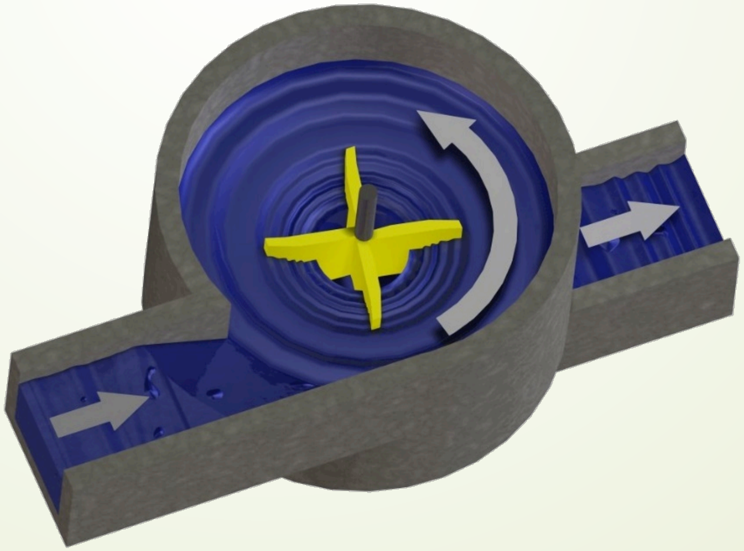
- Conventional hydropower plant uses a dam on a river to store water in a reservoir.
- Water gradually released from the reservoir flows through a turbine, spinning it, which, in turn rotates the armature of generator thus producing electrical power.
- But hydropower doesn't necessarily require a large dam. Some hydropower plants just use a small canal to channel the river water through a turbine.

Abstract

- *This document concerns about the study of Water Vortex Power Plant, an ultra-low head hydropower system. The study commenced with modification of basin geometry and shape with intention of developing more efficient system then conventionally adopted. Research was done in various phase in which different basin geometry were formulated and tested. After determining best geometry, research focused on developing special robust type runner for harnessing more energy from water vortex. Having completed its developmental phases in laboratory study is now heading for pilot project installation. This project is expected to bring changes to life of local people and capacity to adapt to climate change.*

Working Principle

- A low head hydropower system
- Introduced in 2007 first for the purpose of power extraction
- An artificially formed vortex rotated the turbine
- Environmental friendly hydropower system
- Requires less civil structures (low initial investment)



Various Components

Figure : Various Components of Gravitational Water Vortex Power Plant (Courtsey, Zotlöterer)

Performance

Figure : First Power Plant

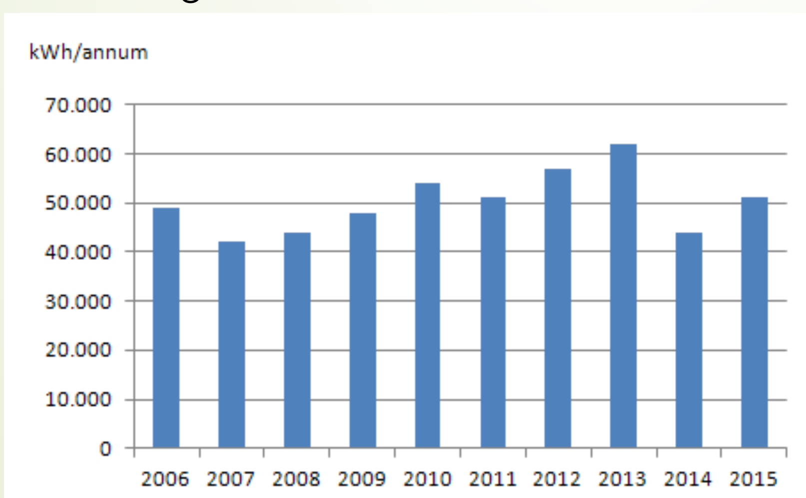


Figure : Annual Generation

- Works by Inventor, Franz Zotlöterer
  - 10 kW plant Installed in Switzerland
  - Monitored annual power generation from it
  - Seen as one reliable, low cost source of energy
  - Total cost of Installation 60,000 Euros
  - Virtually no maintenance after installation (Only bearing oil change)

Basin Geometry Used by Inventor

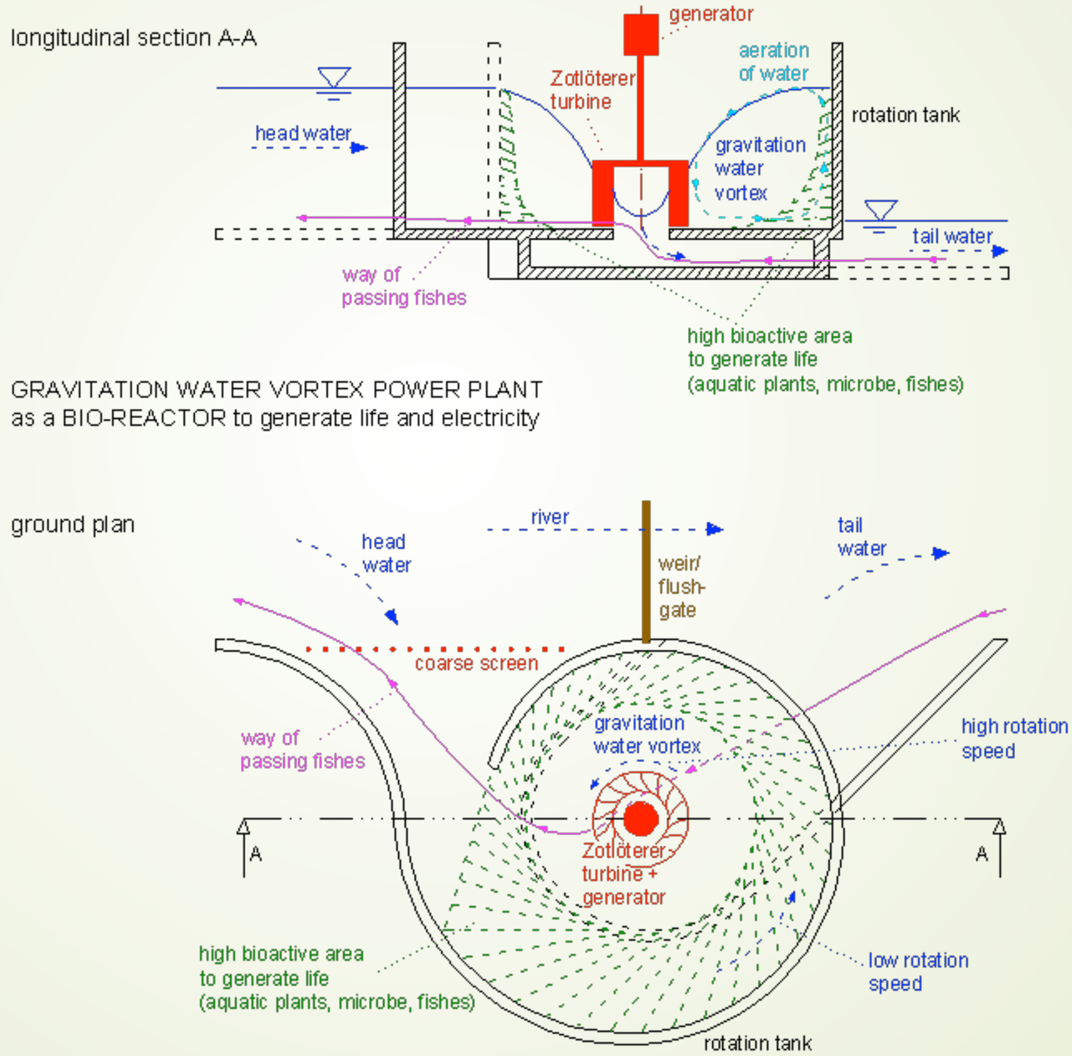


Figure : Layout of Basin Structure

Research Phase I : Change in Cylindrical Basin Geometry

- *Introduction of Vertical gap between bottom of basin and canal base*

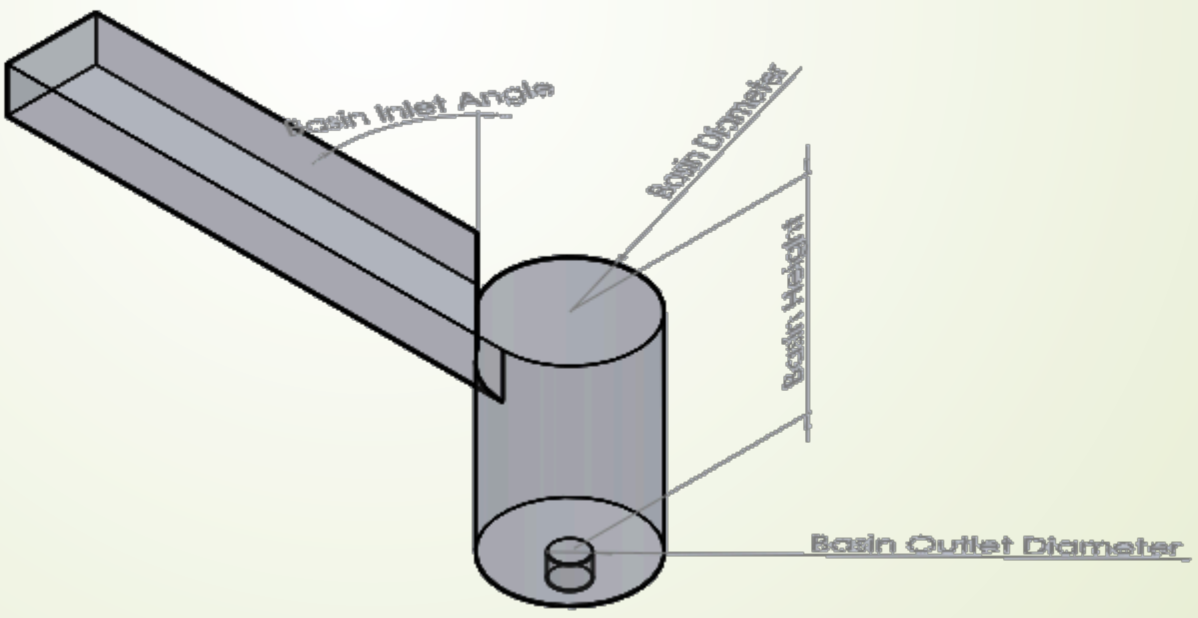


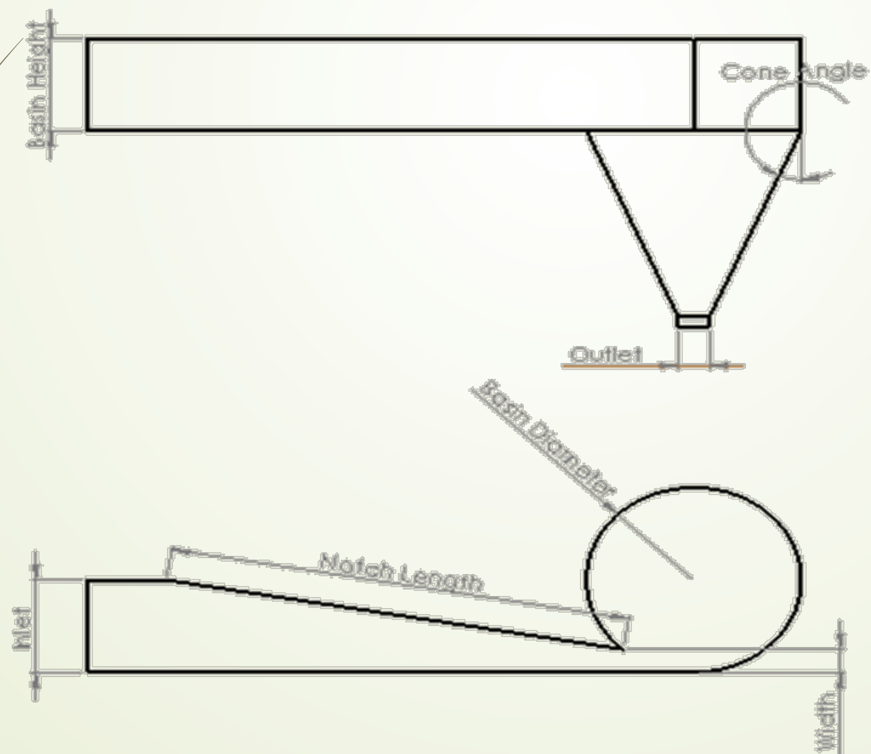
Figure : Nomenclature for Cylindrical Basin

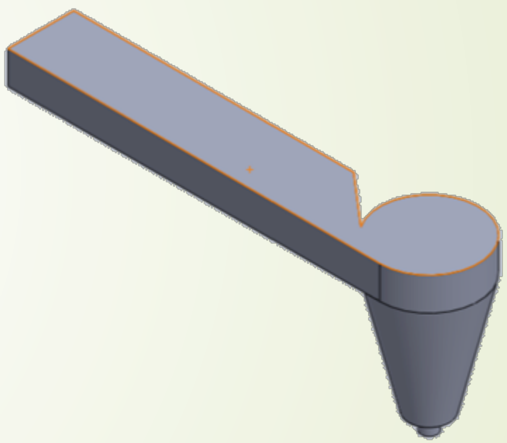
Key Findings in Phase-I

- For a fixed discharge condition, the height of basin, diameter and bottom exit hole are fixed
- In sufficient flow condition, velocity of water around the central vortex seemed to be higher than at inlet to the basin
- For larger exit hole, same discharge used for smaller exit hole does not form smooth vortex
- As countermeasure to maintain smooth vortex, either discharge should be increased or basin height or basin diameter should be decreased

Research Phase II : Change in Basin Shape

- *Introducing conical shape for vortex formation*
- *Testing for Runner Design*





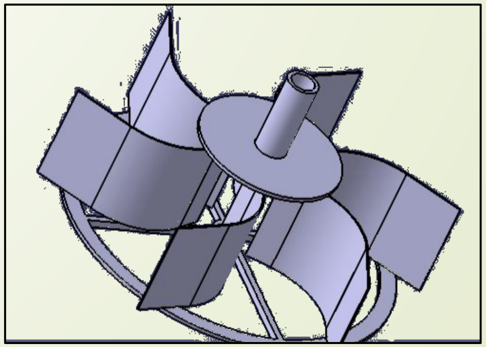
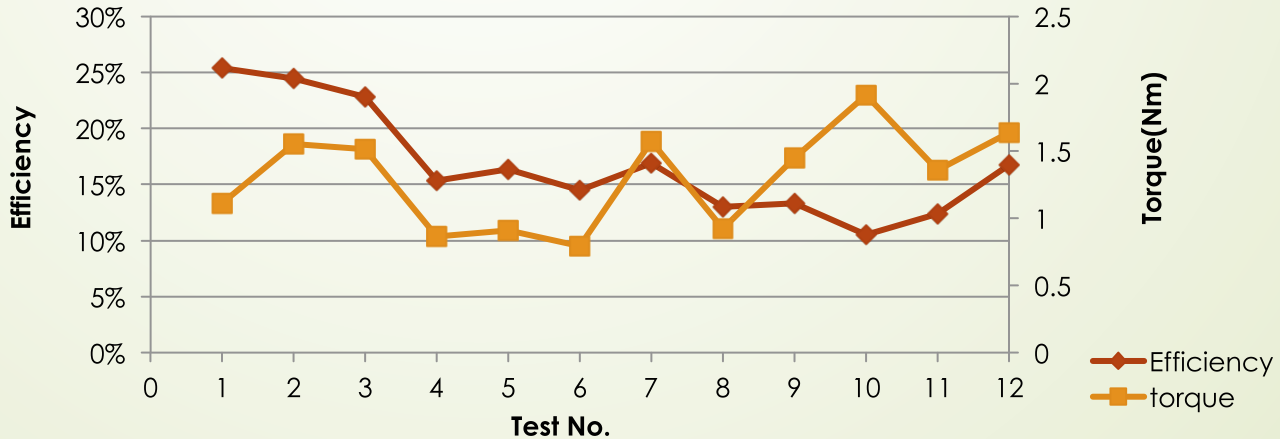


Figure : Nomenclature for Conical Basin

Key Findings in Phase-II

- Strength comparison between the vortexes formed with conical and cylindrical basins shows that vortex formation was aided by conical basin.
- Efficiency was higher for turbines with smaller number of blades. There was a significant distortion of vortex even with smaller loads in case of the turbine configuration with greater number of blades
- Increase in the radius of the blades decreases the efficiency of turbines because of friction at the inner surface of the basins



Site Testing

Figure : Installation in Manohara River, Bagmati, Nepal

Research Phase III : Comparative Study & Optimization

- *Design Optimization by Numerical Modeling and Experimental Verification*
- *Test Rig Development for Runner Development*

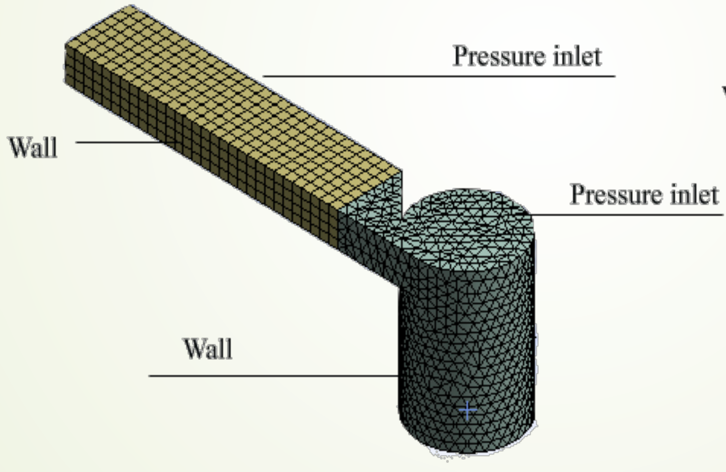


Figure :
Boundary Conditions, Cylindrical basin

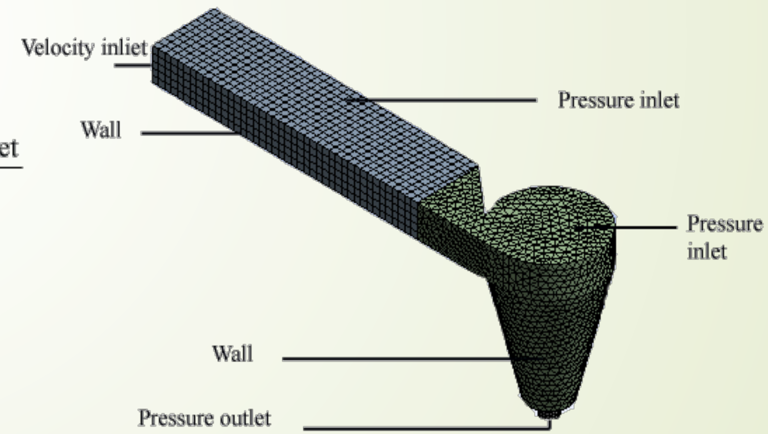


Figure :
Boundary Conditions, Conical basin

Key Findings

- Dominant parameters that determine the basin design of GWVPP were identified with their significance showing that basin opening was most important parameter to be considered during design of GWVPP
- Different studies done on conical and cylindrical basin showed that conical basin was more efficient. Thus the conical basin was optimized for a given head and flow using GLM model
- Superiority of conical basin was verified experimentally using same runner in different basin

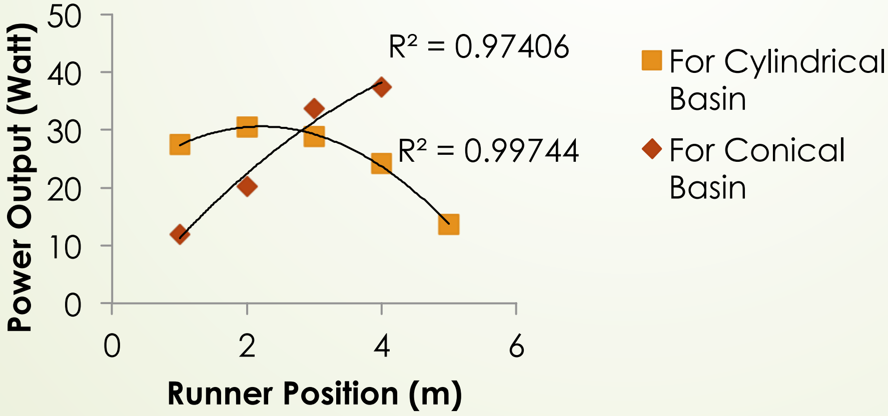


Figure : Performance Comparison

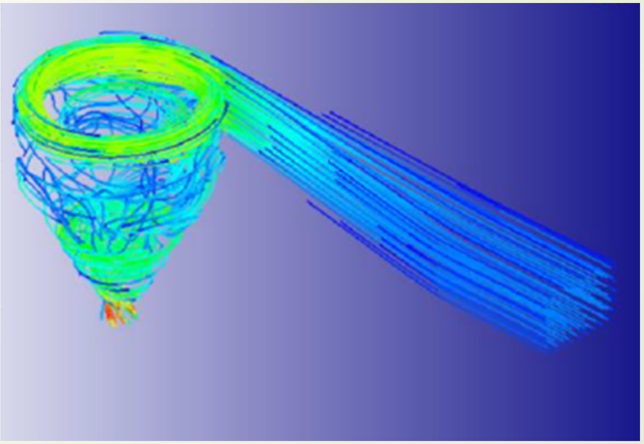


Figure : Streamlines for Conical Basin

Development of Test Rig for Runner Development

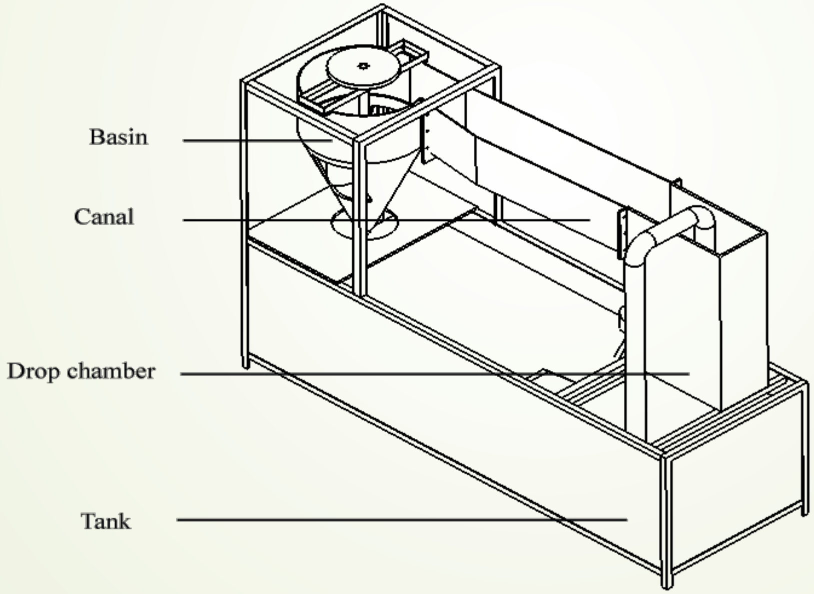


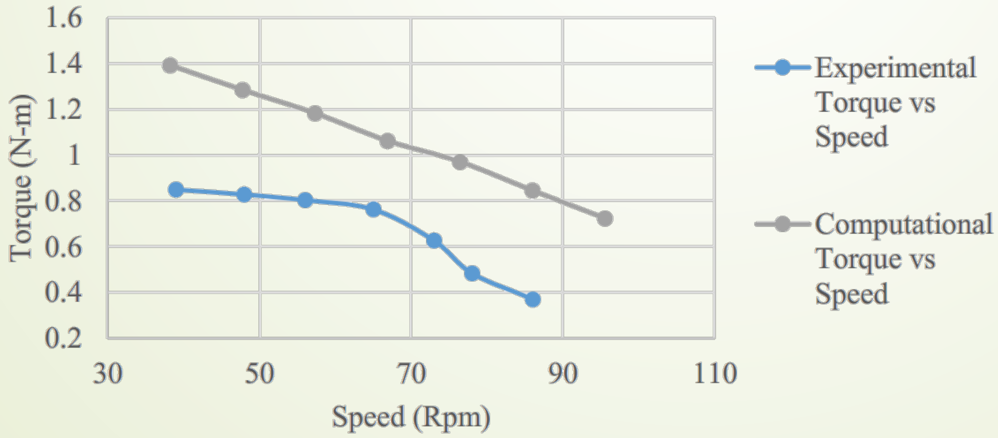
Figure : Test-rig for Testing Various Runner

Research Phase – IV
Runner Development

Figure : Various Runner Fabricated for Experimental Study

Key Findings

- Determined the optimum impact angle of water i.e., the inclination of runner blade with the vertical. The impact angle was found to be 21 degrees
- Generated optimum profiles considering different dimensions and parameters
- Addition of booster turbine in series vertically at the lower zone of basin increases the speed and hence output power



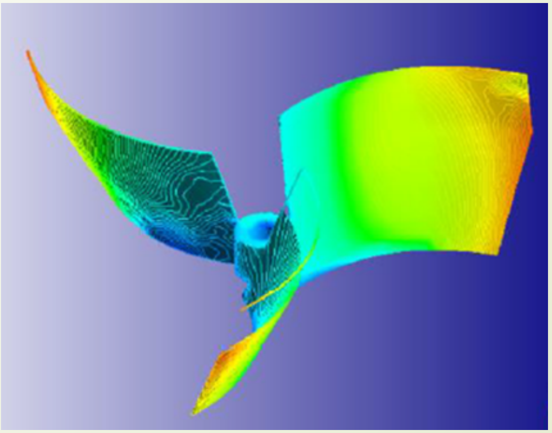


Figure : Optimized Runner and Its Performance Curve

Research Publications

- Bajracharya, T. R. & Chaulagai, R. K., 2012. *Developing Innovative Low Head Water Turbine for Free-Flowing Streams Suitable for Micro-hydropower in Flat (Terai) Regions in Nepal,* Kathmandu: **Center for Applied Research and Development(CARD), Institute of Engineering, Tribhuvan University, Nepal.**
- Bajracharya, T. R. et al., 2013. *DEVELOPMENT AND TESTING OF RUNNER AND CONICAL BASIN FOR GRAVITATIONAL WATER VORTEX POWER PLANT,* Kathmandu: **Journal of the Institute of Engineering, 2014**
- Sagar Dhakal, Ashesh Babu Timilsina, Rabin Dhakal, Dinesh Fuyal, Tri Ratna Bajracharya, and Hari P. Pandit. Effect of dominant parameters for conical basin: **Gravitational water vortex power plant. International Conference on Technology and Innovation Management & IOE Graduate Conference, 5(2):111 – 115, 2015**.
- Dhakal, Sagar, Ashesh Babu Timilsina, Rabin Dhakal, Dinesh Fuyal, Tri Ratna Bajracharya, Hari Prasad Pandit, Nagendra Amatya, and Amrit Man Nakarmi. 2015. "Comparision of cylindrical and conical basins with optimum position of runner : Gravitational water vortex power plant." ***Renewable and Sustainable Energy Reviews* 662-669**.
- Sagar Dhakal, Ashesh B. Timilsina, Rabin Dhakal, Dinesh Fuyal, Tri R. Bajracharya, and Hari P. Pandit. Design optimization of basin and testing of runner for gravitational water vortex power plant. **HydroVision 2015.**
- Anil Sapkota, Ankit Gautam, Jhalak Dhakal, Subash Neupane, and Shreeraj Shakya. Design Study of Runner for Gravitational Water Vortex Power Plant with Conical Basin, 2016. **IOE Graduate Conference 2016**

Research Phase - V
Installation of Pilot Project

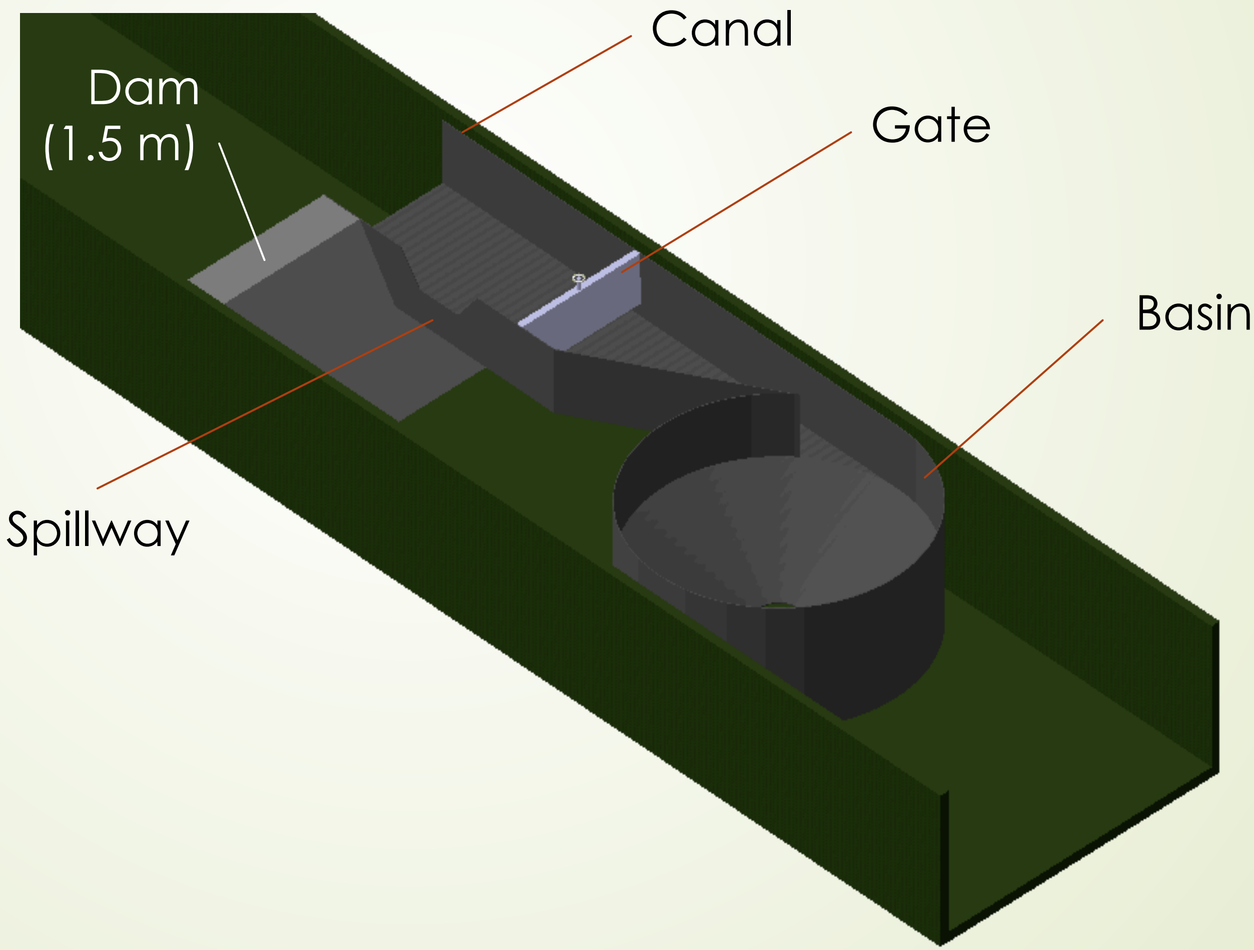
- *Proposed Site for Pilot Project of 1kW*

Site Summary

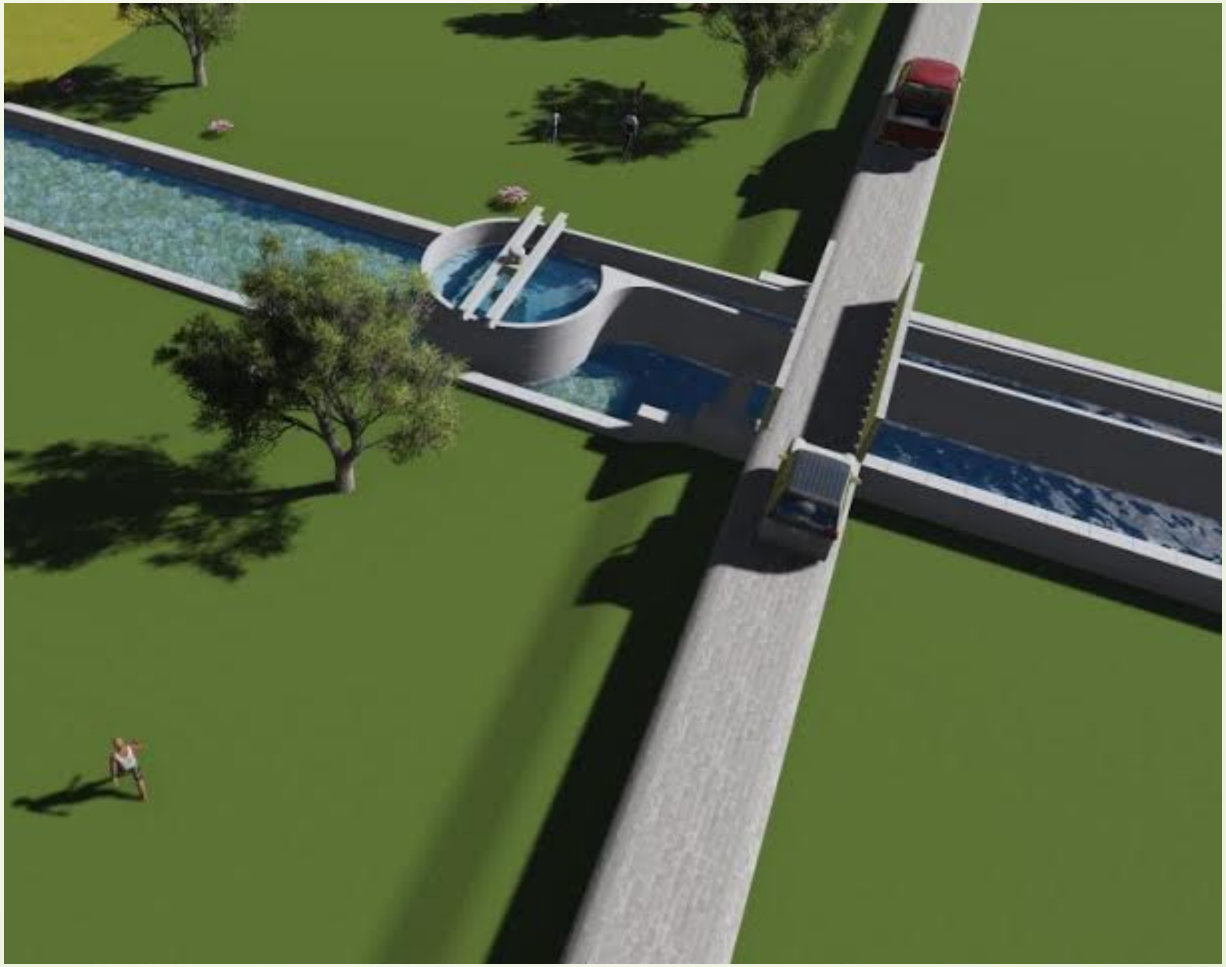
- Location : Thakurdwara, Bardiya, Nepal
  (Inside Bardiya National Park)
- Existing purpose of Canal : Irrigation
- Flow rate : 1.6 m^3/s , Net Head : 1m
- Local Ethnic group : Tharu People
- Major source of Income : Agriculture, Seasonal Tourism
- Number of Household : approx. 200
- Major Energy Consumption : Firewood
- Major Energy Expense : Cooking
- Current use of Alternative Energy : Solar for Lighting by some households only.

Nepal, Geographical Map

Proposed Layout for 1kW (Civil Works)



Finally,



Expected Output

- Decreased dependency on solid fuel for lighting and heating water
- Developed system can be installed in fields and power can be used for lighting, ploughing and develop lift type irrigation system.
- Decreased emission and thus Indoor air pollution
- Technology can independently be developed and promoted in Nepal.

Climate Change Issues in Prospected Sites

- The prime area of installation of these type of units will be flat region of Nepal, the Terai
- Terai region is region that produce surplus cash crops to support whole country
- Major source of energy in these areas is direct burning of solid fuels thus emitting more carbon in atmosphere
- Much reliance on rainfall and limited areas irrigated with irrigation canal and traditional means of agricultural practice mean that changes in climatic conditions can alter production
- Threat to production of these crops due to changes in climatic conditions like temperature, precipitation etc.
- Reduction in bio-diversity, which might also significantly effect production

Addressing Issues with Technology

- Developed technology can be installed in existing river, canal as it does not require much civil structure
- Reduction in emission and deforestation by replacing solid fuels with electricity
- Creating means to pump water for irrigation, making independent from rainfall
- Creating job opportunities, improving GDP and living standard thus the capacity to adapt to climate change

Thank you!