Development of Francis turbine at Kathmandu University to initiate a new business in Hydropower market under Himalayan basins

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World: Hydropower Potential

- South America: 13%
- North America: 16%
- Europe: 18%
- Australia/Oceania: 1%

Total World: 1225 GW

- Africa: 2%
- Asia: 50%

Developed

Ref: Hydropower Status Report, IHA, 2016

Planned


Asia: Hydropower history

1897, India
Sidrapong Hydropower Station
2*65 kW
2017: 51.98 GW (61.87% of TF)

1911, Nepal
Pharping Hydro Power Project
2*250 kW
2017: 0.867 GW (1.84% of TF)

1912, China
Shilongba Hydroelectric Power Station
2*240 kW
2017: 331.11 GW (41.47% of TF)

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**Status of Hydropower Development: Nepal**

<table>
<thead>
<tr>
<th>S.N.</th>
<th>Summary status of hydropower development</th>
<th>No. of projects</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Completed projects</td>
<td>80</td>
<td>937.31</td>
</tr>
<tr>
<td>2</td>
<td>Projects under construction</td>
<td>57</td>
<td>4935</td>
</tr>
<tr>
<td>3</td>
<td>Issued construction licenses for generation</td>
<td>148</td>
<td>4322.59</td>
</tr>
<tr>
<td>4</td>
<td>Issued survey licenses</td>
<td>289</td>
<td>13397.85</td>
</tr>
<tr>
<td>5</td>
<td>Application received for survey licenses</td>
<td>23</td>
<td>2084.16</td>
</tr>
<tr>
<td><strong>Total (2-5)</strong></td>
<td></td>
<td><strong>24739.56</strong></td>
<td></td>
</tr>
</tbody>
</table>

Ref: Department of Electricity Development, Government of Nepal, 2017

**South & South East Asia**

<table>
<thead>
<tr>
<th>Country</th>
<th>Tech feasible (GWh/year)</th>
<th>Installed (MW)</th>
<th>Planned (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afghanistan</td>
<td>25000 MW</td>
<td>400</td>
<td>~500-1000</td>
</tr>
<tr>
<td>Bhutan</td>
<td>&gt;99250</td>
<td>1615</td>
<td>8530</td>
</tr>
<tr>
<td>Cambodia</td>
<td>8600 MW</td>
<td>1267</td>
<td>4378-6513</td>
</tr>
<tr>
<td>India</td>
<td>660000</td>
<td>51494</td>
<td>~1000098500</td>
</tr>
<tr>
<td>Laos</td>
<td>20000 MW</td>
<td>4168</td>
<td>4000-17000</td>
</tr>
<tr>
<td>Lebanon</td>
<td>1500</td>
<td>221</td>
<td>200-300</td>
</tr>
<tr>
<td>Myanmar</td>
<td>39720 MW</td>
<td>3140</td>
<td>10000-17000</td>
</tr>
<tr>
<td>Pakistan</td>
<td>204000</td>
<td>7264</td>
<td>~17000-20000</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>8250</td>
<td>1624</td>
<td>&gt;267</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>71423</strong></td>
<td><strong>54975-169425</strong></td>
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</tbody>
</table>


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### Hydropower Challenges in Nepal

#### Sediment Concentration and Erosion rates for major river basins in Nepal

<table>
<thead>
<tr>
<th>River Basin</th>
<th>Quartz Content [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Seti</td>
<td>70</td>
</tr>
<tr>
<td>Jhimruk</td>
<td>60</td>
</tr>
<tr>
<td>Rapti Khol</td>
<td>50</td>
</tr>
<tr>
<td>Madi River</td>
<td>40</td>
</tr>
<tr>
<td>Ganaha</td>
<td>30</td>
</tr>
<tr>
<td>Arun Khol 2</td>
<td>20</td>
</tr>
<tr>
<td>Modhi Khol</td>
<td>10</td>
</tr>
<tr>
<td>Aadi Khol</td>
<td>0</td>
</tr>
<tr>
<td>Kulekhani</td>
<td>0</td>
</tr>
<tr>
<td>Chitlang</td>
<td>0</td>
</tr>
<tr>
<td>Palung</td>
<td>0</td>
</tr>
<tr>
<td>Bagmati</td>
<td>0</td>
</tr>
<tr>
<td>Manahara</td>
<td>0</td>
</tr>
<tr>
<td>Dhobi</td>
<td>0</td>
</tr>
<tr>
<td>Roshi</td>
<td>0</td>
</tr>
<tr>
<td>Dhad Khol</td>
<td>0</td>
</tr>
<tr>
<td>Khinti</td>
<td>0</td>
</tr>
<tr>
<td>Khimi Khol</td>
<td>0</td>
</tr>
<tr>
<td>Tamakoshi</td>
<td>0</td>
</tr>
<tr>
<td>Phedhi</td>
<td>0</td>
</tr>
<tr>
<td>Dolal Ghat</td>
<td>0</td>
</tr>
<tr>
<td>Sunkoshi</td>
<td>0</td>
</tr>
<tr>
<td>Sapt Koshi</td>
<td>0</td>
</tr>
</tbody>
</table>

**Figure:**
- 4 MW*3 Francis runner at Jhimruk Hydroelectric Center, Nepal
- 1.7 MW*3 Pelton turbine Andhi Kholo Hydro power plant Nepal

**References:**
- B. Ole G. Dahlhaug, 2004
- O.G. Dahlhaug, 2004
Turbine Design Philosophy and Performance

Operational range of Francis turbine

Sediment Erosion ∝ Velocity

48 MW*3 Francis turbine at Kaligandaki-A Hydroelectric Center, Nepal,
Ref: B. Chhetri, 2013

250 MW*6 Francis runner at Nathpa Jhakri Powerplant, India
Ref: H.K. Sharma, 2010

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## Loss of Energy Generation

### Table: Energy Losses

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Kaligandaki ‘A’</td>
<td>NEA</td>
<td>144.00</td>
<td>750.84</td>
<td>0.78</td>
<td>7.51</td>
<td>583,178.25</td>
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<tr>
<td>2</td>
<td>Mid-Marsyangdi</td>
<td>NEA</td>
<td>70.00</td>
<td>435.56</td>
<td>0.78</td>
<td>4.36</td>
<td>338,298.07</td>
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<tr>
<td>3</td>
<td>Marsyandi</td>
<td>NEA</td>
<td>69.00</td>
<td>441.74</td>
<td>0.78</td>
<td>4.42</td>
<td>343,096.39</td>
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<tr>
<td>4</td>
<td>Kulekhani I</td>
<td>NEA</td>
<td>60.00</td>
<td>71.36</td>
<td>0.78</td>
<td>0.71</td>
<td>55,422.14</td>
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<tr>
<td>5</td>
<td>Kulekhani II</td>
<td>NEA</td>
<td>32.00</td>
<td>36.06</td>
<td>0.78</td>
<td>0.36</td>
<td>28,004.16</td>
</tr>
<tr>
<td>6</td>
<td>Trishuli</td>
<td>NEA</td>
<td>24.00</td>
<td>125.03</td>
<td>0.78</td>
<td>1.25</td>
<td>97,107.34</td>
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<tr>
<td>7</td>
<td>Modi</td>
<td>NEA</td>
<td>14.80</td>
<td>62.79</td>
<td>0.78</td>
<td>0.63</td>
<td>48,766.76</td>
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<tr>
<td>8</td>
<td>Devighat</td>
<td>NEA</td>
<td>15.00</td>
<td>94.31</td>
<td>0.78</td>
<td>0.94</td>
<td>73,247.76</td>
</tr>
<tr>
<td>9</td>
<td>Sunkoshi</td>
<td>NEA</td>
<td>10.05</td>
<td>35.99</td>
<td>0.78</td>
<td>0.36</td>
<td>27,956.66</td>
</tr>
<tr>
<td>10</td>
<td>Jhimruk</td>
<td>BPC</td>
<td>12.00</td>
<td>72.00</td>
<td>0.78</td>
<td>0.72</td>
<td>55,922.33</td>
</tr>
<tr>
<td>11</td>
<td>Khimti I</td>
<td>HPL</td>
<td>60.00</td>
<td>350.00</td>
<td>0.78</td>
<td>3.50</td>
<td>271,844.66</td>
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<tr>
<td>12</td>
<td>Chilime</td>
<td>CHC</td>
<td>22.1</td>
<td>137.90</td>
<td>0.78</td>
<td>1.38</td>
<td>107,106.80</td>
</tr>
<tr>
<td>13</td>
<td>Bhote Khosi</td>
<td>BKPC</td>
<td>45</td>
<td>293.2</td>
<td>0.78</td>
<td>2.932</td>
<td>227,728.16</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>555.85</strong></td>
<td><strong>2906.76</strong></td>
<td></td>
<td><strong>29.07</strong></td>
<td><strong>2.25 Million</strong></td>
</tr>
</tbody>
</table>

Annual generation for NEA’s power plants are given for 2072-2073
Ref. Nepal Electricity Authority, Annual Report 2073

![Thermodynamic efficiency measurement at Jhimruk HPP](image)

Other Financial Losses

- Repair and Maintenance Costs
- Downtime Costs

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Turbine Manufacturing Experiences of Nepal

• 1962: First turbine manufactured in Nepal, 5 kW Propeller
• 1973: First Crossflow turbine manufactured in Nepal
• 1975: First Pelton turbine manufactured in Nepal
• 2016: Turbine manufactures 58, Unit Capacity upto 100 kW
  Total capacity 30 MW, Export 0.6 MW

Malaysia, 40 kW, 1987
Bhutan, 100 kW, 1997
Turbine Testing Lab at KU

**Major Objectives:**
- Performance Testing of Hydraulic Machines
- Development of New Turbines
- Education and Training
- Applied Research to Solve Problems of Hydropower Industry

**Specifications:**
- 30 m Open System Head
- 150 m Closed System Head
- 500 l/s Maximum Flow
- 300 kW Maximum Testing Capacity
- 300 m³ Lower Reservoir
- 100 m³ Upper Reservoir
- 5000 kg EOT Crane Capacity

**Financial Contributions**

- **Total USD 1.3 Million**
  - 60% KU
  - 20% Local HP Institute
  - 20% NORAD

Inaugurated on 10 November 2011
Kickoff Francis Turbine R&D at TTL, 2012

Development of 2 kW Francis Runner

CAD Model

3D Printer

Plastic section of a runner sector

Wax section

CAD Model

3D Printer

Plastic section of a runner sector

Wax section

Test results

Rig for turbine testing

Casted runner after finishing

Wax runner with vents

Plaster mold for runner
Development of 92 kW Francis Turbine
TTL Activities and Achievements

Academic Activities:

<table>
<thead>
<tr>
<th>Activities</th>
<th>Completed</th>
<th>Ongoing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhD</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>MS by research</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Masters Thesis</td>
<td>17</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>Undergraduates thesis</td>
<td>51</td>
<td>8</td>
<td>59</td>
</tr>
<tr>
<td>Journal Publications</td>
<td>35</td>
<td>5</td>
<td>40</td>
</tr>
</tbody>
</table>

Test Facilities:

- 5 kW Crossflow turbine test rig and procedures, *KETEP, 2013*
- 20 kW Crossflow turbine test rig and procedures, *AEPC, 2014*
- 22 kW Pelton turbine test rig and procedures, *AEPC, 2014*
- 92 kW Francis turbine test rig and procedures, *EnergizeNepal, 2016*

Certification and Services:

<table>
<thead>
<tr>
<th>Activities</th>
<th>Client</th>
<th>year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test certification of 1 kW Pico-propeller turbine</td>
<td>PEEDA</td>
<td>2012</td>
</tr>
<tr>
<td>Design validation of 100 kW Crossflow turbine</td>
<td>UTS</td>
<td>2013</td>
</tr>
<tr>
<td>Detail study of root crack in 12 MW Pelton runner</td>
<td>HPL</td>
<td>2014</td>
</tr>
<tr>
<td>Design and analysis of penstock bifurcation for 6 MW HPP</td>
<td>Daraudi HPP</td>
<td>2014</td>
</tr>
<tr>
<td>Detail design of 300 kW Francis turbine (under discussion)</td>
<td>IPS</td>
<td>2017</td>
</tr>
</tbody>
</table>

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Future Strategy:

Center of Excellence (CoE)

Technology and Entrepreneurship
CoE at TTL for Hydropower Development

**Aim:** Nepalese hydropower industries capable to produce hydro turbines addressing local and regional technical challenges through continuous research and development activities

<table>
<thead>
<tr>
<th>Components</th>
<th>Goals</th>
<th>Vision 2022</th>
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</thead>
<tbody>
<tr>
<td><strong>Model Testing</strong></td>
<td>Establish IEC standard Francis turbine test facilities serving at the regional level.</td>
<td>Model test of commercial projects, at least one, at each national and regional level.</td>
</tr>
<tr>
<td><strong>Turbine Design and Manufacturing</strong></td>
<td>Initiate turbine manufacturing in Nepal with the new design technology for reducing sediment erosion.</td>
<td>System design of electromechanical components with 5 MW unit size Francis turbine manufactured in Nepal.</td>
</tr>
<tr>
<td><strong>Services and Training</strong></td>
<td>Provide technical services and trainings for repair, maintenance and operation of turbines in sediment-laden projects.</td>
<td>Third party quality control of turbine repair. Services for efficient power plant operation. Training packages for different target groups.</td>
</tr>
</tbody>
</table>
Previously Proposed Models for Business

- Both models were focused to develop technical competence in University and transfer it to Industry.
- University was in leading role to initiate new business, which was not successful.
The forward step: A Breakthrough

• A private limited company by a team with high professional experience in design and development of hydropower systems in the leading role.
• Design and Research experts from Universities in supporting role.
• Consortium providing a complete ‘water-to-wire’ solution for hydropower.
• The solution includes analysis, design, manufacture or supply and maintenance of all electro mechanical equipment in hydropower projects.
• By 2030 the company should aim to develop a complete in-house technology for design and manufacture of turbine components for up to 25 MW unit size.

A collaborative initiative of Industries and Academia
Need of Sustainable Partnership

- **Lead Partner Company**
  - Provide technical and non-technical service as per need.
  - Maintain cash flow as per need of project.
  - Fulfill relevant regulations and procedures (PPA, EIA etc)
  - Coordinate for design, installation and commission of relevant components.
  - Deliver complete water-to-wire EM solution.

- **Manufacturing Facilities**
  - Manufacture and supply of turbine and other components as per drawings.
  - Detail design of turbine. Manufacturing drawings. Support for manufacturing and commissioning.
  - Manufacture or supply of other components and axillaries as per order.

- **Design Experts (University CoE)**
  - Provide technical and non-technical service as per need.

- **Suppliers/Companies**
  - Resource persons/team

- **Investors**
- **Government Agencies**
- **Project Developer**
- **Civil and HM Contractors**
Goal: Maximize Profit with high quality service

Production and service unit
Main business: EM parts
  Design
  Manufacturing
  Trading
  Installation
  Commissioning
  After sales service

Business under scope:
  • Operation of power plant
  • Repair and maintenance
  • Hydro mechanical parts

  • Turbine center
  • Shaft to shaft position
  • Crane sizing
  • Load on civil structure

  • Power plant design
  • EM system design
  • Component design

  • Turbine components
  • Additional components
  • Others…

  • Major (Generator, Control systems, Valves)
  • Additional (Cooling, Protection, …)
  • Others…

  • Periodic maintenance
  • Routine maintenance
  • Spare parts
  • Capacity building

Sales and Marketing unit
  • Market study
  • Business development
  • Projects and contracts

Finance and HR unit
  • Investments & Risks
  • Human Resources
  • Infrastructure
  • Facilities

  • Turbine specifications
  • Generator specifications
  • Control system specifications
  • Cooling system specifications
  • Protection system specifications

  • Turbine design
  • Mechanical components
  • Electrical components

  • Turbine detail design
  • Turbine production drawings
  • Retention of IPRs

  • …
  • …
  • …
  • …

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**Business Development Plan**

### Incubating Phase:
- Acquire IPR for one reference
- Basic manufacturing facility
- Outsource only runner for manufacturing
- Start service on turbine repair

### Progressing Phase:
- Acquire IPR for three references
- Well equipped facility for turbine manufacturing
- Develop turbines for rehabilitation projects

### Leading Phase:
- Develop independent design competence
- Capacity for electrical equipment
- Complete EM solution up to 10 MW

### Sustenance Phase:
- Capacity up to 30 MW
- Compete in international market
- Retention of HR and expertise
- Retention of partnerships

### The Pilot Project:
- Project consortium
- Acquire pilot project
- Outsource manufacturing
- Lesson learned

### Investments on manufacturing facilities

### Investments on electrical facilities

### Suggested Name
QUARTZ HYDRO

### Net capital
- 2018: 400 kW
- 2020: 2 MW
- 2024: 10 MW
- 2028: 50 MW
- 2030: 100 MW

### Total project awarded
- $5000

### Investments on manufacturing facilities

### Investments on electrical facilities

### Suggested Name
QUARTZ HYDRO

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Open Discussion: **The Stakeholders**

- **C1 – Patron Promoters:** Original business idea, Incubate the company
- **C2 – Preliminary EM Design & Engineering, Project Execution**
- **C3 – Business Development, HR, Finance**
- **C4 – Trading, Installation, Commissioning**
- **C5 – Production Planning & Control, Manufacturing, Assembly, Installation**
- **C6 – Turbine Testing Lab:** Detail design of turbine, Manufacturing Drawings, Test Certification, QA
- **C7 – KU-Faculties, Researchers & Students**
- **C8 – Special/Reserved Shares:**

**QUARTZ HYDRO**

**Authorized Capital:** USD 2 Mil
**Paid-up capital:** USD 0.5 Mil
Executive The Pilot Project

**Project Specifications:**
- Head=50 m
- Flow=1 m³/s
- Rated Power= 2*150 kW

**EM Specifications:**
- 2*175 kW Francis turbines
- 2*200 kVA synchronous generators at 750 rpm
- 400 kVA transformer
- ...

**Objectives:**
- To build the consortium.
- To validate design and manufacturing strength.
- To create a reference case for developers and investors.
- Background and motivation for future projects.
- Lesson learned.

**University Partners (KU-NTNU CoE)**
- Turbine specifications for system design
- Detail design of turbine components
- Manufacturing drawings for industry
- Support for manufacturing and commissioning

**Lead Partner**
- Project administrations and management (contracts, finance, tender, risk, HR, …)
- Design of power house
- System design and selection of EM components
- Manufacturing of turbine components and accessories
- Procurement of other EM components
- Installation, commissioning and follow-ups

**Resource persons/team**
- Manufacturing Industry Suppliers/Companies
- Deliver product or services as per agreement

**Project Developer**
- License issues and investments
- Project site and specifications
- Civil construction, HM and other installations
- Support during installation and commissioning
- Responsible for power end use or sales

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Challenges/ Discussions

• Formation of the project consortium and company.
• Role of design experts (University CoE) in overall business.
• Response from Hydropower market and existing players.
• Design competence and guarantee issues on turbine design.
• Industrial capacity for turbine manufacturing.
• System integration of components from different suppliers.
• Acquiring and completing the pilot project.
• Conflicts of mutual interest between partners.
• Support from hydropower industry and government.
Thank you!