SUSTAINABLE HYDROPOWER FOR THE 21ST CENTURY
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Millison’s Hydro experience

- 2002 Zhanghewnan Pumped storage
- 2002-03 Xiaogushan Hydro 98 MW
- 2004-06 India Uttarkhand MFF: grid expansion to support 2000+ MW of large hydro
- 2013-14 Nepal SASEC: grid expansion to support 2000+ MW of large hydro + RE mini-grids
- 2014-16 India Assam Lower Kopili 120 MW
Nepal hydro: an embarrassment of riches?

- Economic potential: 40,000+ MW
- Installed: < 2% of potential 787 MW
- 61 plants
- Average size 12.9 MW
- Only 1 > 100 MW - Kaligandaki A 144 MW
- Today only 3 plants under construction with capacity > 100 MW, including Upper Tamakoshi 456 MW

What’s wrong with this picture?
Traditional Design: Maximize MW

\[ P = n \times p \times g \times Q \times H \]

• Traditional design basis:
  – 40-70% reliable flow Q40 to Q70
  – 4000 hours per year @ rated capacity (PLF ~ 50%)
  – Ignore risks until design is fixed, then try to de-risk

• Sustainable Design: Optimize MW-hours
• Modular: Ashta 50 MW hydro IFC
Knowledge base for sustainability by design

- 1970 Aswan High Dam
- 1990s Pangue (Chile) & Narmada (India)
- 2001 World Commission on Dams
- 2003 World Bank *Good Dams, Bad Dams*
- 2006 - 2010 International Hydropower Association sustainability rating system
- 2013 Ashta 50 MW modular hydro IFC
- 2014 Ansar *et al* – *Should we build more large dams?*
- 2015 Poff *et al* – ecological engineering decision scaling
# Traditional vs. Sustainable Design

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Conventional Approach</th>
<th>Sustainability Approach</th>
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<tbody>
<tr>
<td>High up-front capital cost</td>
<td>Inherent in traditional development approach</td>
<td>Down-scale capacity; modular design</td>
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<tr>
<td>Hydrological risk</td>
<td>Q40 – Q70</td>
<td>Design for Q90</td>
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<tr>
<td>Geological Risk</td>
<td>Related mainly to dams and tunnels</td>
<td>Overflow or trench weirs. Low-head design with multiple smaller installations.</td>
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<tr>
<td>Permitting Risk</td>
<td>Multiple parties at central, state/provincial, and local level; difficult to satisfy all stakeholders.</td>
<td>Minimize by shift to smaller installations based on sustainability principles</td>
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<td>Land Acquisition Risk</td>
<td>Local opposition to resettlement cannot always be de-risked</td>
<td>Include local land-owners and non-titled tenants into project ownership structure</td>
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<tr>
<td>Construction Risk</td>
<td>Related to geological risks</td>
<td>Minimize through modular design using simplest generation technology (ASG)</td>
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<tr>
<td>Environmental and Social Risk</td>
<td>Largely ignored until late in development process</td>
<td>Ecological engineering decision scaling eliminates most risks upfront.</td>
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<tr>
<td>Revenue Risk</td>
<td>Mainly related to financial health of off-taker</td>
<td>Can be reduced indirectly by shifting to smaller capacity design with faster pay-back period</td>
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Modular design: more power faster = more $$$ faster

Power Output Comparison (MWh/y)

- Conventional 100 MW
- Modular 50 MW

+131 GWh with Modular design
Modular design: less equity, higher return

Cash Flow Comparison

+131 GWh @ $0.10/kWh
upfront revenue = $13.1 M
= 8.7% of total cost @ $3 M/ MW

This is what CARBON FINANCE has NOT done !!!
ASGs: minimum moving parts, simple civil works, fish friendly, OK for high sediment loads
ASGs: At outlet of sewage treatment plants
ASGs: At outlet of sewage treatment plants
ASGs: At tailrace at existing larger hydro plants
“Policymakers, particularly in developing countries, are advised to prefer agile energy alternatives that can be built over shorter time horizons to energy megaprojects.”

– Atif Ansar

REFERENCES


• International Hydropower Association Sustainability Assessment Protocol
  http://www.hydrosustainability.org/

• N. LeRoy Poff, Casey M. Brown, Theodore E. Grantham, John H. Matthews, Margaret A. Palmer, Caitlin M. Spence, Robert L. Wilby, Marjolijn Haasnoot, Guillermo F. Mendoza, Kathleen C. Dominique and Andres Baeza, Sustainable water management under future uncertainty with eco-engineering decision scaling. Nature Climate Change, Perspective, Published online: 14 September 2015. DOI: 10.1038/NCLIMATE2765


• Additional Notes on ecological engineering decision scaling:
  http://source.colostate.edu/researchers-building-better-dams-starts-with-ecological-insights/
  http://alliance4water.org/events/files/2014_xi_9a.html

• Natel Energy Schneider Linear Hydroturbine; notes that shifting from high-head / large dam to multiple smaller low-head installations gets about 90% of power output while flooding less than 10% of land area, and using 1/3 of the concrete:
  http://www.natelenery.com/vision/ecosmarthydro/