Standard Module Hydropower (SMH): How Do We Enhance the Economic, Environmental, and Social Benefits of New Small Hydro Development?

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Outline

State of small hydro
(refers to plants with <10 MW of capacity in this document)

What does the current fleet of U.S. small hydropower assets look like?

Shepherding a new approach

How can we design standardized, scalable, low-cost, low-impact hydropower systems?

Collaborative R&D

How do we work together to achieve better outcomes?
Small hydro projects (SHPs, <10MW) by the numbers

3.8 GW from over 1,700 plants with roughly 3,500 individual turbines providing 0.3% of U.S. annual net electricity generation.
Regulatory expectations for SHPs

3.8 GW from over 1,700 plants with roughly 3,500 individual turbines providing 0.3% of U.S. annual net electricity generation.
Highly competitive energy landscape producing few new small hydro projects

Rapidly declining solar and wind coupled with cheap natural gas make conventional SHPs increasingly economically unattractive

SHPs are competing directly with wind and solar

Example new, low-head, SHP cost distribution

Result: Three new stream-reach (not on canals/conduits/non-powered dams) SHPs greater than 1 MW constructed in past decade in U.S.
Common environmental impacts and mitigation requirements

Based on a review of over 300 SHPs that were relicensed between 1998 and 2013

For relicensed SHPs

<table>
<thead>
<tr>
<th>Environmental mitigation requirement</th>
<th>% of SHPs under study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recreational management plan study or monitoring</td>
<td>71%</td>
</tr>
<tr>
<td>Run-of-river tailrace</td>
<td>49%</td>
</tr>
<tr>
<td>Operations compliance monitoring plan</td>
<td>48%</td>
</tr>
<tr>
<td>Sediment and erosion control plan or monitoring</td>
<td>43%</td>
</tr>
<tr>
<td>Water quality monitoring plan</td>
<td>43%</td>
</tr>
<tr>
<td>Species conservation management monitoring</td>
<td>36%</td>
</tr>
<tr>
<td>Other day use area improvements</td>
<td>36%</td>
</tr>
<tr>
<td>Tailrace flow monitoring plan</td>
<td>35%</td>
</tr>
<tr>
<td>Canoe portage launch</td>
<td>30%</td>
</tr>
<tr>
<td>Parking</td>
<td>27%</td>
</tr>
</tbody>
</table>

Source: ORNL

Anticipated for new SHPs

Environmental Attributes of NSD Sites with <10MW Potential

- Fish Passage Concern
- Habitat Concern
- Recreation Passage Concern
- Water Quality Concern

For new SHPs with <10MW Potential:
- Total # of <10MW sites
- Potamodromous fish species in watershed
- Federally listed fish species in watershed
- Fish species of concern in watershed
- Whitewater runs within 500m
- Critical habitat within 300m
- 303d listed waterbodies within 500m
- Wild and scenic rivers within 2500m
- Boat ramps within 500m

Number of Sites

Source: ORNL
Resource potential for new SHP Development

29 GW of cumulative NSD potential at 10,000 sites with less than 10 MW of installed capacity

New Stream-reach Development (NSD) Potential by Subbasin for the United States (as of 2014)

Majority of NSD sites are low-head (< 30ft) compared to existing fleet

Existing and potential small hydropower projects

Source: ORNL
New SHP development – at a crossroads

Multipurpose benefits of hydro

<table>
<thead>
<tr>
<th>Carbon free energy</th>
<th>Dependable, reliable generating capacity</th>
<th>Local and national economic investment</th>
<th>Long asset life</th>
<th>Avoided greenhouse gas emissions</th>
<th>Avoided water withdrawals for electricity</th>
<th>Recreation opportunities</th>
</tr>
</thead>
</table>

Poor project economics and environmental complexity

Site-specific design, site-specific impacts, long and uncertain regulatory process

Renewable energy competition

Rapid deployment of new low-cost wind and solar capacity
Shepherding a new approach – Standard Modular Hydro (SMH)

How do we design standardized, scalable, low-cost, low-impact hydropower systems?

**Modularity** for cost reductions and scalability

**Standardization** for cost efficiency and consistency

**Environmental function** as a cornerstone of facility siting, design, and operation

**Stakeholder elicitation** to codify values, criteria, and thresholds of acceptance early in the design process

**Shifting conventional SHP thinking**

- **Site-specific** → **Modular**
- **Custom** → **Standardized**
- **Maximize power** → **Sustain stream functions**
- **Stakeholder reluctance** → **Stakeholder acceptance**
Shepherdung a new approach – Standard Modular Hydro (SMH)

How do we design standardized, scalable, low-cost, low-impact hydropower systems?

Consider a conventional facility as modular subsystems designed and optimized for generation, passage, and foundation functions.

Representative ‘virtual’ conventional small hydro development
Modularity across the facility

Modularity across the facility (i.e., balance of plant) is not currently a proven or accepted concept.

Assembly of the entire SHP from prefabricated modules that scale across a single site and across multiple sites

- Recreation – Fish – Sediment – Water

Modularity across the facility (i.e., balance of plant) is not currently a proven or accepted concept.

Scalable Passage Modules – recent innovations from industry

- Modular kayak/fish passage and water passage
  - Spatial scaling based on fish jumping height and Froude number that will not create dangerous hydraulic jump

Source: MKEC Engineering
**Modularity across the facility**

Modularity across the facility (i.e., balance of plant) is not currently a proven or accepted concept.

**Assembly of the entire SHP from prefabricated modules that scale across a single site and across multiple sites.**

**Scalable Generation Modules – recent innovations from industry**

Modular variable speed composite turbine/generator

Modular form incorporating turbine and generator in single unit

Scaling based on flow

Source: Amjet

http://www.amjethydro.com/
Modularity across the facility
Modularity across the facility (i.e., balance of plant) is not currently a proven or accepted concept

Assembly of the entire SHP from prefabricated modules that scale across a single site and across multiple sites.

Scalable Foundation Modules – recent innovations from industry

Precast modular foundation and civil works

Modular form for ease of manufacturing and transportation

Source: FDE
http://www.fdepower.com/

Scaling based on width and head at a site
Standard design specification

Using a holistic understanding of watershed scale functionality to develop standard design specifications

Standard design specification for classes of modules and modular facilities

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Passage</th>
<th>Foundation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constraints</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures of performance</td>
<td></td>
<td></td>
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</tbody>
</table>

Ex: Upstream Fish Passage Module

Requirements
- Attract fish to module inlet
- Enable fish to cross the SMH facility
- Allow fish to exit safely into the river
- Integrate structurally into foundation module

Constraints
- slope
- max drop height
- min/max velocity
- cost

Performance
- attraction
- passage rate
- time delay
- injury

http://hydropower.ornl.gov/smh/publications/
Standard method to classify environmental characteristics
Identification and grouping of stream-reaches with similar environmental characteristics into finite # of classes

Identification and grouping of stream-reaches with similar environmental characteristics

Example: Land Use

Example: Mean Annual Streamflow

Example water quality characteristics:
Mean annual streamflow, population density, terrain, land use, soil type, impervious %, summer air temperature, etc.

Clusters provide an idea of where similar module designs can be deployed

<table>
<thead>
<tr>
<th>Cluster #</th>
<th># of stream reaches</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38,000</td>
<td>Unforested, low agricultural, low erodibility</td>
</tr>
<tr>
<td>2</td>
<td>31,000</td>
<td>Agricultural, high erodibility</td>
</tr>
<tr>
<td>3</td>
<td>55,000</td>
<td>Forested, low erodibility</td>
</tr>
</tbody>
</table>
Goal: to create a ‘technology agnostic’ facility and environmental design specification applicable at one or many clusters.

Vision: if it works well at one site, it should work at other sites within the same cluster.
Moving the needle towards a sustainable SHP future

Standard modular hydropower has the potential to enhance the economic, environmental, and social benefits of new development.

Shifting conventional SHP thinking

- Site-specific
- Custom
- Maximize power
- Stakeholder reluctance

Modular

Standardized

Sustain stream functions

Stakeholder acceptance

Economic Benefits
- Cost reductions through use of same module designs
- Scalable facility designs
- Site classification for early identification of need

Environmental Benefits
- Maintaining or improving stream health
- Sustaining or restoring connectivity
- Hydropower facilities as environmental monitoring platforms

Social Benefits
- Enhancing recreation opportunities
- Strengthening project acceptance
- Job creation and knowledge transfer
Collaboration as a key to success

Standard modular hydropower will only be successful through collaboration across diverse stakeholder groups

http://hydropower.ornl.gov/smh/
Thanks for your time

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