Standard Modular Hydropower:
Environmentally compatible, low-cost technology acceleration

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Presentation Theme

Environmentally compatible, low-cost technology acceleration

NWHA Small Hydro Buyer’s Workshop
Smart, Sustainable Hydropower

ORNL/DOE Standard Modular Hydropower
Environmentally Compatible, Low-Cost Hydropower

for more information, visit: hydrosource.ornl.gov & smh.ornl.gov
State of Hydropower Development

• Most hydropower installed from 1950 to 1990

• Types of hydropower development
  – Pumped storage
  – Upgrades
  – Non-powered dams (NPDs) and other water conveyances
  – New stream-reach development (NSD)
    • Significant, undeveloped hydropower resource
    • Environmental and economic challenges

• Based on DOE’s Hydropower Vision comprehensive business-as-usual modeling scenario:
  – “New stream-reach development will require transformational innovation before significant development will occur.”

## Standard Modular Hydropower: Motivation

We are at a crossroads with respect to development of new low-head small hydropower facilities:

**Benefits of small hydro** – *includes many valuable, non-power benefits!*

<table>
<thead>
<tr>
<th>Renewable and 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>
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### Environmental impacts and ecosystem complexity
Site-specific design, site-specific impacts, long and uncertain regulatory process

### Difficult project economics and renewable energy competition
High capital costs and competition from rapid deployment of new low-cost wind and solar capacity
Standard Modular Hydropower: Food for Thought

What if…?

…we could quickly and comprehensively identify the design requirements of a new hydropower site?

…we could automate early-stage project analysis and develop standard, modular, environmentally compatible configurations?

…we could use rapidly manufactured low-cost standard modular technologies to build the facility?

Site Identification and Environmental Data Analytics

Modular Technology Acceleration

Standard Modular Facility Designs

- Recreation – Fish – Sediment – Water
- Passage
- Generation
- Foundation
Standard Modular Hydropower: Motivation

The big question for small hydropower’s future: Can we develop low-cost, modular, replicable hydropower facilities that preserve or enhance river function?

SMH research goal: stimulate innovative designs that incorporate standardization, modularity, and environmental compatibility as enabling design principles of small, low-head hydropower facilities

**Standardization:**
Standard siting methods, designs & technologies, manufacturing, project review, regulatory pathways, construction sequencing, etc. to reduce site specificity and project costs.

**Modularity:**
The physical organization of a hydropower facility into discrete functional units, allowing scalability to deliver energy and environmental benefits at many different sites.

**Environmental Compatibility:**
Facilities sited and operated as coupled human-natural systems to minimize disturbances to maintain stream functionality and ecosystem health.
The Standard Modular Hydropower Concept

Hydropower technology that is:
• standardized (i.e., replicable)
• modular (i.e., scalable)
• environmentally compatible
• low-cost, low-impact

ORNL Technology Acceleration R&D
SMH Site Classification &
SMH Explorer
Co-development
SMH Exemplary Design
Envelope Specification
Technology & Environmental
R&D for Modules & Facilities

Innovation

Stakeholder Engagement
Test Driving SMH Concepts through Industry
Partnerships & DOE-funded Awards
Technology Development & Demonstration
SMH Exemplary Design Envelope Specification

A framework for technology-neutral (“black box”) SMH conceptual design

- **Fish Passage**: allow the unimpeded and safe passage (upstream and downstream) of fish through a SMH facility
- **Recreation Passage**: allow the passage of small recreational craft consistently and safely through a SMH facility
- **Sediment Passage**: allow the transport of incoming sediment through a SMH facility
- **Generation**: generate hydroelectric power from flowing water under pressure
- **Water Passage**: convey non-generating water over or through the SMH facility
- **Foundation**: anchor passage and generation modules to the streambed and banks

![Diagram showing Facility Black Box and Module Black Boxes with Inputs and Performance](image-url)
SMH Explorer: web-based geovisual analytics platform

https://smh.ornl.gov/explorer/

SMH Site Classification → SMH Explorer

SMH Explorer provides information on stream-reach and project relevant variables to inform early site scoping.

National classification of streams based on a statistical analysis of many characteristics

Sediment
Foundation
Energy
Water Quality
Fish
Recreation
Reach, watershed, and landscape area-specific data...

dozens of variables per US stream-reach

...can help a project developer understand the modular design objectives of a stream-reach
Hydropower Co-Development: Realizing Non-Power Value

**Hydropower co-development:** Development of an energy project that also enhances or improves the environmental conditions of a stream-reach.

- **Water quality improvement.** Can small modular facilities drive water quality improvements while generating energy?
- **Recreational park.** Can dual purpose hydropower and recreation facilities lead to greater acceptance from stakeholders?
- **Hydrologic restoration.** Can small modular facilities help restore favorable hydrologic conditions and flow regimes while generating energy?
- **Low-flow at existing hydro.** Can a standard modular package improve low flow handling while generating energy?
- **Low-head non-powered dam.** Can a modular energy/environmental/recreation solution provide the same benefit?

Ongoing and Future Research Efforts

• Continuing SMH module/facility-related research and development, with near-term focus on non-powered dam application

• Test-driving SMH technology concepts through DOE-funded funding opportunity announcements (FOAs)
    • Objective: stimulate innovative design concepts for small, low-head hydropower plants capable of lowering the capital costs and reducing the environmental impacts of development at new stream-reach (i.e., greenfield) sites
    • Awardees: Littoral Power Systems & Natel Energy
  – DE-FOA-0002080, Area of Interest 2a: Modular Technologies for Low-Head Hydropower Applications
    • Objective: focus on the design and production of entirely new standardized, modular hydropower technologies for low-head applications (30 feet or less)
Standard Modular Hydropower: Concept Animation

https://www.youtube.com/watch?v=hyVryO1VOGA
Thank you for your time!

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Back-up Slides
Standard Modular Hydropower: Motivation

Resource potential for new SHP development

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

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

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Examples of Technology Innovation

From the DOE Hydropower Vision Report:

• Emerging strategies:
  – compact, integrated turbine/generator units
  – fabrication using alternative materials and additive manufacturing
  – elimination of traditional penstocks and powerhouses
  – fish-friendly turbines “help avoid or minimize the environmental impacts of hydropower operations”
Standard Modular Hydropower Site Classification

Objective: To group similar stream reaches into a finite number of clusters based on characteristics/variables that can be used to inform both need and design requirements for a module type.

Classification for each module type

- Fish Passage
- Recreation
- Sediment
- Generation
- Water Quality
- Foundation

Classification Units
Single stream-reach (i.e., site)

Clustering Variables

In-stream
- Physical
  - Hydrology
  - Gradient
  - Geomorphology
- Biological
  - Species present

Landscape (local or regional)
- Land use
- Soil type
- Impervious surfaces
- Existing dams and mitigation

Geo-political
- Population density

300,000+ NHD stream reaches with mean annual flow between 50 - 25,000 cfs
SMH Exemplary Design Envelope Specification
A framework for technology-neutral ("black box") SMH conceptual design

Inputs
• variables that govern stream and module behavior

Objectives
• primary function to be achieved as a result of deploying and operating a module

Requirements
• a behavior or function that must be performed by a module for successful operation

Constraints
• a limitation on the value of a design parameter or an operation

Performance
• a set of quantifiable indices or metrics that enable the evaluation of how well an objective is met

Functional relationships
• parametrized linkage of inputs to objectives and performance
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Facility Black Box
Module Black Boxes

Inputs
Performance

Objectives
Requirements
Constraints
Functional relationships
Hydropower Co-development Framework

Co-development templates

• Low-flow at existing hydro
• Low-head non-powered dam
• Hydrologic restoration
• Water quality improvement
• Recreational park

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Accelerate technology for co-development

= SMH site with standard technology package

Geospatial analysis, data aggregation, and site ranking

Upstream
feedbacks and interdependencies

Downstream
feedbacks and interdependencies

Standard Modular Concept Designs

System and facility modeling

Hydrology
Hydraulics
Geomorphology
Water Quality
Ecologic Response
Energy

Industry-led Innovation

Accelerate technology for co-development

Economics

Industry

Geospatial analysis, data aggregation, and site ranking

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