SLH100 demonstration project at Monroe Hydro

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Project Overview

The Challenge:

10,000 GW+ potential exists for low-head hydro projects globally. In the United States, 2–4 GW potential in U.S. constructed waterways, 8–12 GW in U.S. non-powered dams, and 100+ GW in new stream development.

Installation constraints and high civil works have made low-head hydro development economically unfeasible.

Natel Energy designed, developed, and now operates Monroe Hydro, a 250 kW low-head hydropower plant on North Unit Irrigation District's Main Canal in Madras, Oregon that runs Natel's SLH100 hyroEngine®.

Partners: North Unit Irrigation District, Bureau of Reclamation

Next Generation Hydropower (HydroNEXT)

Optimization

- Optimize technical, environmental, and water-use efficiency of existing fleet
- Collect and disseminate data on new and existing assets
- Facilitate interagency collaboration to increase regulatory process efficiency
- Identify revenue streams for ancillary services

Growth

- **Lower costs of hydropower components and civil works**
- Increase power train efficiency for low-head, variable flow applications
- Facilitate mechanisms for testing and advancing new hydropower systems and components
- Reduce costs and deployment timelines of new PSH plants
- Prepare the incoming hydropower workforce

Sustainability

- Design new hydropower systems that minimize or avoid environmental impacts
- Support development of new fish passage technologies and approaches
- Develop technologies, tools, and strategies to evaluate and address environmental impacts
- Increase resilience to climate change

Next Generation Hydropower (HydroNEXT)

Growth

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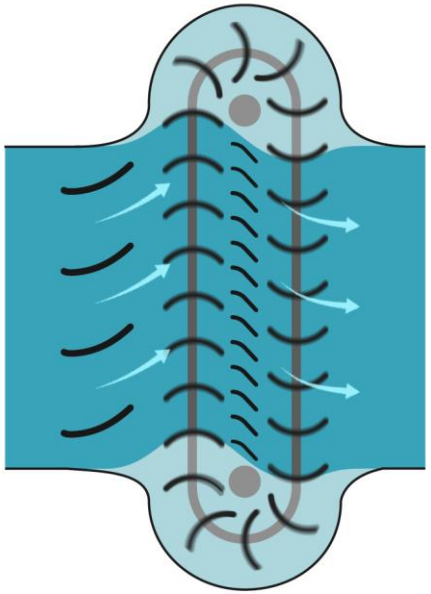
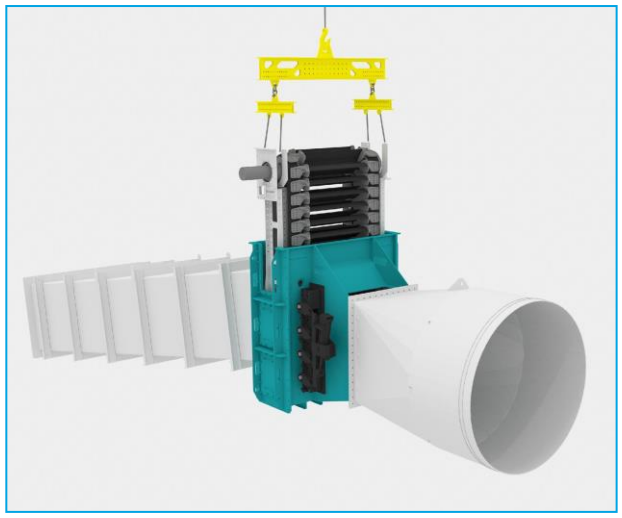
The Impact

- Demonstrate long-term potential to hit $0.07 per kWh
- Successful deployment of Natel's hydroEngine, and realizing the associated plant construction cost savings, will open up low-head water ways for development, including 10,000 + GW potential worldwide
- This project, in particular, has accomplished the first step in Natel's commercial deployment roadmap, namely:
  - Demonstrated the ability and further potential to reduce civil works cost.
  - Demonstrated operation of the first of its kind hydroEngine and define path for further technical innovation
  - Sold project to Apple - demonstration of commercial viability.

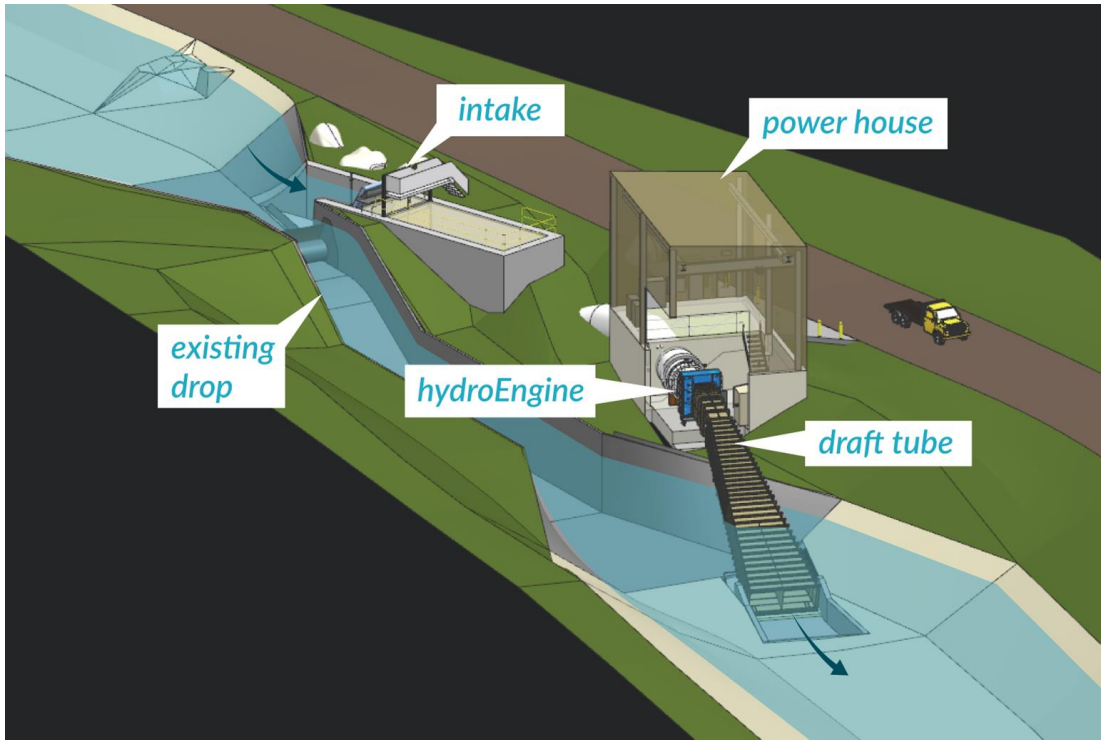
Technical Approach





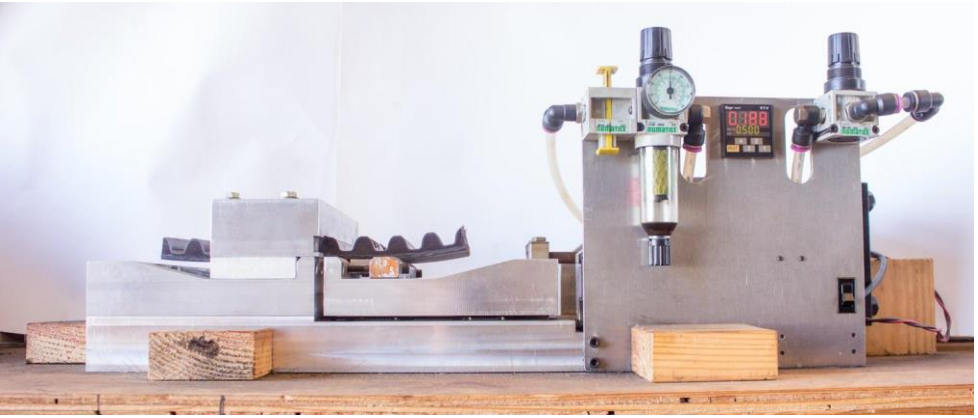
Turbine Innovation: SLH100 hydroEngine

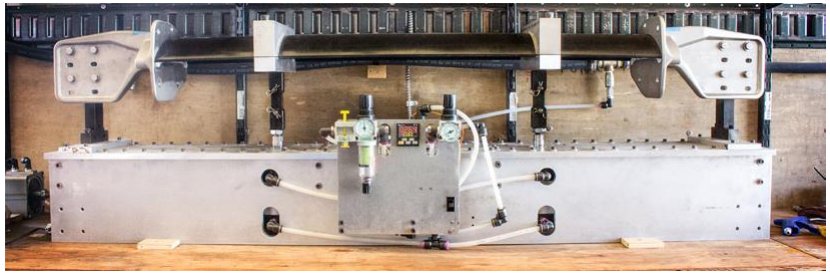
- Linear form factor
- Simple maintenance, modular
- No cavitation



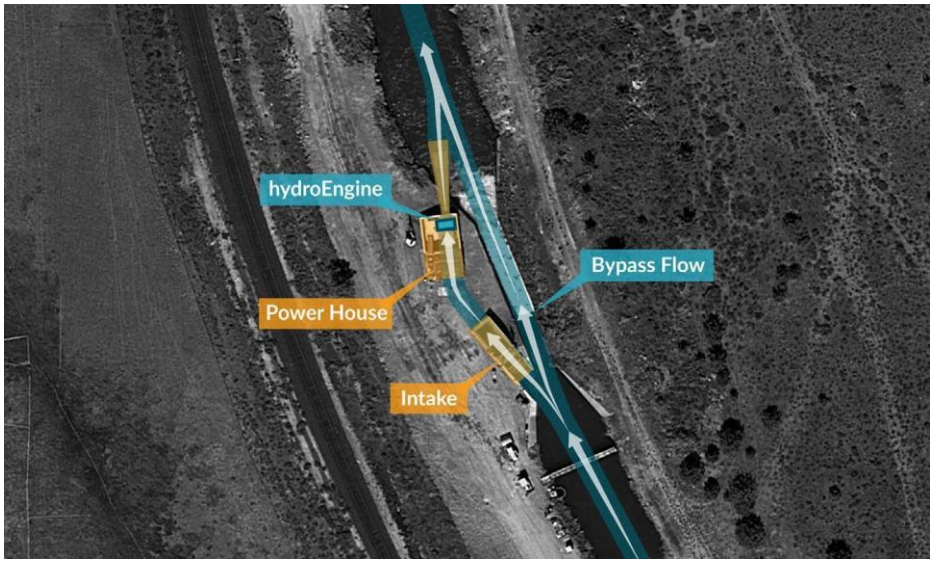
Component level test program before commercial deployment

Test Rig	Test Cycles
Blade endplate clamp	101 million
Blade section- stainless	37 million
Blade section- carbon	48 million / 36 million
Full blade- carbon	101 million
Crossbar	67 million / 107 million
Belt-blade articulation	108 million
Submerged articulation tester	33 million





Accomplishments and Progress



First Federal Energy Regulatory Commission (FERC) conduit exempt project on federal lands.

Operational with 60% w-w efficiency, 73% hydraulic efficiency.

Plant operates autonomously with modern controls system.

Unlevered LCOE of $0.14 with potential to lower to $0.07 target through further reductions in cost of balance of plant systems, civil works, O&M; and through some additional refinements in turbine performance.

Project Plan & Schedule

Since last peer review, project timeline delayed one year

October 2014: FERC Order granted for conduit exemption

<One-year delay; FERC approval took 10 months, causing Natel to miss 2014 construction window>

2015, January – May: Completed civil works & constructed powerhouse.

June: Installed first SLH100 hydroEngine

September: Commissioned 250 kW Monroe Hydro

2016, March: Submitted final report to DOE

May: Demonstrated 15 days of autonomous, continuous operation. Demonstrated water-to-wire efficiency of 60%.

Project Budget

FY2014		FY2015		FY2016	
DOE	Cost share	DOE	Cost share	DOE	Cost share
$313K	$313K	$182K	$283K	N/A	N/A

- Natel increased its cost share to fund increased spend of $90k staff time and $11k in travel

Research Integration & Collaboration

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Partners, Subcontractors, and Collaborators:

- North Unit Irrigation District
- U.S. Bureau of Reclamation
- U.S. Forest Service
- JAL Construction, civil works
- Black Rock Consulting, project engineer
- Apple, plant owner

Communications and Technology Transfer:

- Natel's CEO, Gia Schneider, presented on a panel at 2015 HydroVision entitled, "How Can We Lower the Cost of Conduit and Small Hydro
- Press Coverage: *Irrigation Leader, Harpers Magazine, Popular Mechanics*

Next Steps and Future Research

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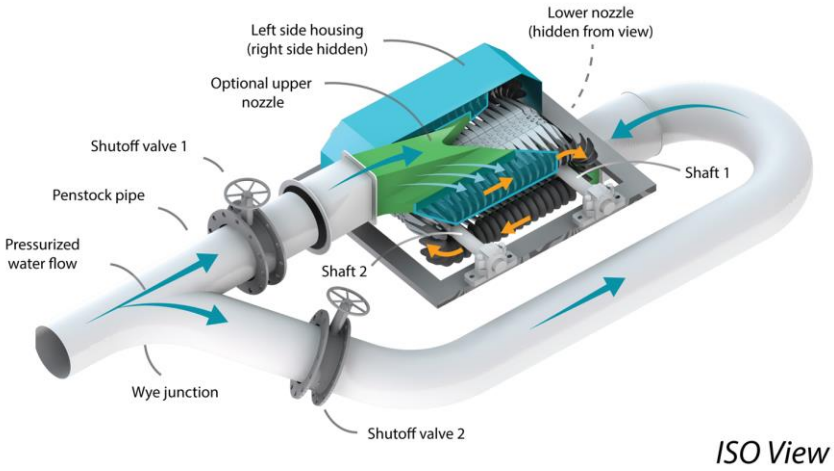
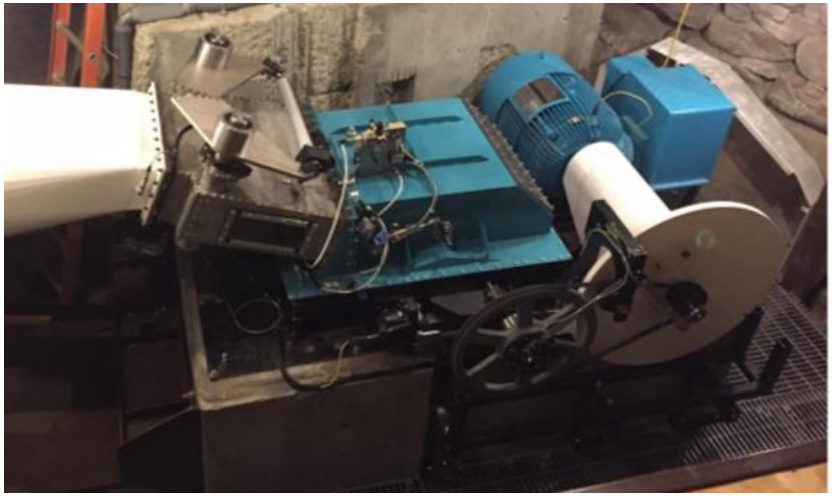
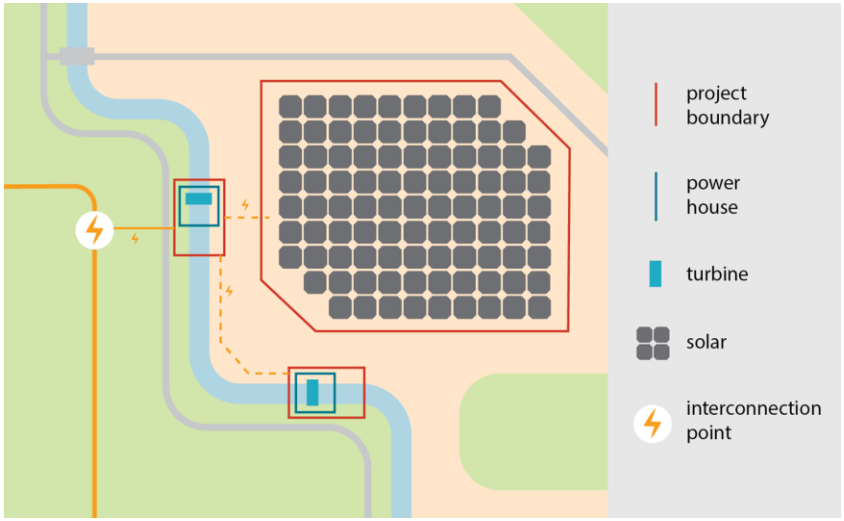
Turbine Innovation



ISO View



Integration with Solar



Civil Works Innovation