Spotlight on power and utility – renewables

A benchmark report on decision-making and investment behavior in hydroelectric equipment
“Hydroelectric equipment is a challenge to the complexity of typical infrastructure projects with its agile economics and standardized technology. Total value of ownership and cooperation in tenders are key to unlock pools of innovation and savings.”

Olivier Bruslé
Power & Utilities Capital and Infrastructure, EY Partner France
Hydropower is considered as one of the most mature, most reliable and least expensive means of energy generation available. Its small variant presents a specific opportunity for electrification capacity deployment and sustainable economic development with an innovation potential for the coming decades. However, it comes with more constraining economics for utilities and challenges to secure the return on investment.

A demanded technology with opportunities in less mature environments

<table>
<thead>
<tr>
<th>Small hydro definition in max. MW</th>
<th>Small hydroelectric power has no common definition in terms of installed MW* capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>50</td>
</tr>
<tr>
<td>China</td>
<td>50</td>
</tr>
<tr>
<td>Brazil</td>
<td>30</td>
</tr>
<tr>
<td>India</td>
<td>25</td>
</tr>
<tr>
<td>EU</td>
<td>20</td>
</tr>
<tr>
<td>Norway</td>
<td>5</td>
</tr>
<tr>
<td>Sweden</td>
<td>1.5 Source: IRENA.</td>
</tr>
</tbody>
</table>

Conversion efficiency
After large hydraulic units and tidal power installations, small hydro displays a 90% conversion rate, outperforming by far conventional coal and oil firing, gas turbines and nuclear fission (40% / 45%) and all other renewables.

Scalability
The technology requires the modernization of existing installations and replacement of mechanical and electrical equipment on civil works for the coming two decades with a potential for innovation and efficiency upgrade, as per the UNESCO World Water Assessment Program (WWAP). Efficiency improvements of 5% / 10% are achievable with a smart combination of operating range extension, new equipment, capacity increase, head loss reduction and operations improvement. New materials and operations efficiency improvement are main vectors for innovation.

Flexibility
The small hydroelectric unit is a flexible technology adaptable to existing civil works and Run-of-River designs that avoid ecosystem-costly dams and a dedicated reservoir. It allows the exploitation of new sites that could not be qualified before. The technology can be run in both central grid settings served by utilities and stand-alone schemes still delivered by OEMs. The installation is possible on existing infrastructure initially built for irrigation or mechanical power generation such as water mills.

Development
Small hydro can address the need for the electrification of rural communities in developing countries that account for the 19% of the world population with no access to electricity (IEA, 2010). It embodies an underpinning instrument for economic development, energy management and poverty alleviation. The technology supports best practices, technical capacities and risk framework advised by international organizations and regional bodies.

Incentive eligibility
Small hydropower is eligible to feed-in tariffs and less sensitive to the social resistance and environmental concerns that accompany large hydraulic power plant (HPP) projects. Public incentives to investment essentially target capacity thresholds ranging between 5MW and 25MW in Western Europe and Asia.

And more constraining economics for developers and utilities
Small hydropower projects come with a business challenge to manufacturers that aim at entering the market: simplicity and Total Value of Ownership (TVO) call for economies of scale on modular and standardized products. Equipment producers serve a fragmented but growing demand in less mature geographies and compete with a populated and often mature supply side. A significant share of investment projects in coming years will focus on the refurbishment and upgrade of existing equipment. Small hydropower displays a lower cost of electricity in EUR/KWh, half cheaper than large hydro on the upper threshold. Small hydro also records higher annual operations and maintenance costs than large hydro due to weaker economies of scale. Therefore, equipment manufacturers need to arbitrate on total cost of ownership against generated revenue and transform customer expectations and perceived value into a specific offering.
Challenges and objectives

Low transparency and flexibility on the value chain often prevent the risk-sharing stakeholders from unlocking pools of innovation and cost-saving opportunities in complex power and utilities projects. Such potential can be tapped by understanding the perceived value and decision-making process on the customer side, and by seizing the key interfaces and resource constraints on the supplier side. Small hydroelectric equipment, though less scaled and capital-intensive – provides a nonetheless valuable case and a challenge. It nurtures the business complexity of combining state-of-the-art infrastructure projects with the agile economics of a standardized equipment.

Hydroelectric equipment design and civil works installation are key in their properties and technological edge but communication between players is impaired by practices and tender protocols that lead to true requirements by utilities and prescribers not being fully understood. Both product and business process designs remain rather traditional and sub-optimized. Mature organizations often display a pool of non-implemented redesign opportunities that can be deployed after considering the total value over the entire selling proposition lifetime.

This report on decision-making and investor behavior in the purchase of small hydroelectric equipment shows the readiness of small hydroelectricity stakeholders to review their requirement set if the full economics of the plant investment and electricity generation are considered as a total value. An opportunity then exists to trigger the product innovations and operations improvements that will carry the duplication of global hydroelectricity production and the overall electricity production capacity expansion of 4,779GW forecasted by 2040.

“Customers would be inclined to revise their requirements, if total value over the plant lifetime is addressed by equipment suppliers in tenders.”

Olivier Bruslé
Power & Utilities Capital and Infrastructure, EY

European manufacturers and service providers are market leaders in small hydroelectric equipment. For the coming decades, they will need to display receptiveness and swiftness toward the demand in a fragmented market that is highly influenced by site specificities and regional practices, while at the same time harnessing the economies of scales necessary to deliver a standardized product with a short design-to-market cycle.

This report combines primary and secondary research and is the result of an investigation specific to the small hydroelectric segment. It unveils the true requirements and the recognition for TVO even for standard hydroelectric installations as well as the need to account for price variability. It reflects the latest state of knowledge from industry professionals and experts involved in the development and operations of small hydroelectric units in three key regions.
3 Approach

Challenges in technology and economics faced by decision-makers in hydroelectric investment, operations and modernization can only be sized in an exhaustive approach that considers the entire life cycle of the equipment in a TVO. This study assessed the importance given by decision-makers of turbogenerator purchase to value drivers and equipment functionalities. It investigated their sensitivity to equipment design modification, thereby exploring their readiness to trigger process and product innovation.

Research methodology

We selected a hydroelectric turbogenerator and its balance of plant (electrical and civil works) for the study, and gathered feedbacks from respondents who participate to the purchase decision of small hydroelectric units in the Americas and Europe and that cover together the entire value chain of Hydraulic Power Plants (HPP).

We questioned business case drivers and asked respondents in 7 different geographies to assess the importance of each value chain contributor. The same assessment is then performed on the functionalities of the turbogenerator and balance of plant. Finally, respondents were asked on their readiness or reluctance to relax the technical specifications related to a specific electrical or mechanical function (i.e. if the functionality is not important, it obtains a lower grade and can be revised).

From levelized cost of electricity (LCOE) to TVO

The levelized cost of electricity (LCOE), also known as levelized energy cost (LEC) is the net present value of the unit-cost of electricity over the lifetime of a generating asset. It simulates the average price that the generating asset must receive in a market to break even over its entire lifetime.

It is derived from the combination of capital expenditure (capex) and operating expenditure including maintenance (opex) on the cost side of the equation, and the generated revenue plus the opportunity upside or downside induced by the market-specific conditions of operation on the revenue side.

The revenue side is derived from the project business case that questions the cash flow required to secure a positive present value of the investment. The revenue is a function of production capacity, plant availability and turbine efficiency.

“Total value considers the variability of prices in the new context of multi-energy sources and smart grids ability to trigger the right economic mix of renewables and fossil energies.”

Dan Michaux
Power & Utilities Capital and Infrastructure, EY

| Energy produced $KW = flow \text{m}^3/\text{second} \times \text{head Meters} \times \text{gravitation} (9.8 \text{m/s}^2) \times \text{turbogenerator efficiency } \% |
| Revenue generated $KWh = \text{nominal capacity } KW \times \text{availability} \text{ Hours} \times \text{capacity factor} \% \times \text{price } \$/KWh |

Value chain focus (share of respondents involved at given stages, in %)

- **Equipment capex**: 75%
- **Global capex**: 62%
- **Opex**: 25%
- **Revenue**: 50%

Despite investors focus on up-front expenditure, capex will be less important due to the current low cost of capital.

*Including electrical balance of plant and civil works

Source: EY analysis.
Our research shows that a significant share of small HPP units customers are ready to relax their requirements on most of the dimensions used to design and choose the dimensions of the equipment if they are convinced that the perceived performance of the power plant will not be adversely affected.

### Surveyed geographies

- **North America**
- **Latin America**
- **Western and Central Europe**

### Respondents profile

- **Engineering consultants**
  - Colombia
  - Germany
  - Sweden
  - Georgia
- **Independent power producers (IPP)**
  - Canada
  - Turkey
  - United States

### A potential for innovation driven by total value perception

#### Lifetime cost perspective

**Capex**
- Turbine/Generator + Plants
- Installation
- Electrical BOP
- Non-electrical BOP

**Opex**
- Normal operations
- Corrective maintenance

#### Revenue at nominal price

- Energy production
- Electricity quality

#### Upsides & downsides

- Market conditions
- Environment
- Brand equity

#### Assessment of the relative importance of unit lifetime cost (LCOE) & revenue functions & ups/downsides to decision-makers

- Ease of installation
- Delivery time

#### Relative importance of turbogenerator functions to decision-makers

- Governing system
- Minimize overspeed
- Reduce vibrations
- Generator power
- Output fluctuation

#### Exploration of product and process innovation opportunities on the hydroelectric power plant

- Design for product innovation
- Design for process innovation
Purchasers of small hydroelectric equipment are focused on capex and revenue aspects, and are ready to relax their specifications on turbogenerator technical aspects if international norms are secured and their business case kept in check. They are in turn reluctant to review those aspects, the modulation of which may have health, safety and environment implications. Room to maneuver therefore exists to raise client awareness on their revenue equation, independently from the chosen method to compute equipment efficiency.

**Tapping pools of innovation**

Readiness & resistance to renegotiate technical specifications if the power output, availability & revenue of the power plant are protected within the business case assumptions

<table>
<thead>
<tr>
<th>REVENUE</th>
<th>OPEX</th>
<th>Corrective maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy production</td>
<td>Normal operations</td>
<td></td>
</tr>
<tr>
<td>- Specifications that carry revenue generation and unit availability during operations</td>
<td>- Generator power</td>
<td>- Electricity quality</td>
</tr>
<tr>
<td>- Setting of machine</td>
<td>- Voltage</td>
<td>- Overpressure in penstock</td>
</tr>
<tr>
<td>- Turbine durability</td>
<td>- Voltage variation</td>
<td>- Overload</td>
</tr>
<tr>
<td>- Turbine &amp; generator efficiency</td>
<td>- Excitation type</td>
<td>- Output fluctuation</td>
</tr>
<tr>
<td>- Generator power</td>
<td>- Temperature of bearings</td>
<td>- Over-speed</td>
</tr>
<tr>
<td>- Time without water cooling</td>
<td>- Critical bending speed</td>
<td>- Runaway speed</td>
</tr>
<tr>
<td>- Shaft material</td>
<td>- Frequency variation</td>
<td>- Short circuit ratio</td>
</tr>
<tr>
<td>- Runner stress</td>
<td>- Cavititation</td>
<td>- Sub-transient reactance</td>
</tr>
<tr>
<td>- Vibrations</td>
<td>- Turbine &amp; generator noise</td>
<td>- Cooling system type</td>
</tr>
<tr>
<td>- Turbine and generator noise</td>
<td>- Operability range</td>
<td>- Temperature rise in rotor winding</td>
</tr>
<tr>
<td>- Specifications to be negotiated in consideration of the TVO</td>
<td>- TURBINE</td>
<td>- Temperature rise in stator winding</td>
</tr>
<tr>
<td>- Fan type</td>
<td>- Over-pressure in turbine</td>
<td>- Minimum flywheel inertia</td>
</tr>
</tbody>
</table>

**While complying to norms and standards**

- **Turbine and generator noise**
  - ISO 1999 Acoustics: Determination of occupational noise exposure and estimation of noise-induced hearing impairment
  - ISO 2204 Acoustics: Guide to International Standards on the measurement of airborne acoustical noise and evaluation of its effects on human beings

- **Vibrations**
  - ISO 7919-5:2005: Mechanical vibration, evaluation of machine vibration by measurements on rotating shafts, part 5: machine sets in hydraulic power generating and pumping plants
  - ISO 10816-5: Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts, part 5: machine sets in hydraulic power generating and pumping plants

“Hydro investors need to be convinced that any attempt to redesign preserves the perceived value of equipment and HSE standards compliance.”

Baptiste Chassagnard
Power & Utilities Capital and Infrastructure, EY

Hydro purchasers reveal their readiness to relax or remove specification on turbogenerator dimensions that are directly related to load increase, revenue generation and unit cruise-availability for production. Equipment suppliers may choose the most efficient materials or part design to propose an optimized combination of value-to-cost, as long as the compliance norms and standards applicable to the industry are secured.

Balanced ratings address those technological aspects that can be negotiated to issue purchase specifications. Some of the specification can be traded against upsides along the levelized cost of electricity.

Some decision-makers are ready to rely on state-of-the-art specifications suggested by the OEM if it is trusted to keep up on technology advances and material improvements.
5 Implications and evolutions

Customers think in terms of total value of ownership and return on investment but with different levels of maturity in hydroelectric technology, economics and of sophistication in their decision-making criteria and thresholds. Up to utilities and prescribers to open their tender requirements and play the competition. Some equipment manufacturers are innovating around the true needs and values communicated by developers and end users and are starting to deliver enhanced LCOE.

A product definition under business assumption...

From business case to equipment specifications

Turbogenerator efficiency and its calculation is defined for hydroelectric units under the IEC-60041 standard. It is generally used by equipment purchasers and project developers to qualify OEM offers with respect to the operating potential of a certain HPP site in order to assess their ability to realize their forecasted return on investment.

The required quantity of electricity to sell (MWh) allows to derive the necessary power production capacity (MW) considering HPP site data.

This capacity is weighted against environmental factors such as site head, flow, hydrology authorizing production, and equipment-related factors such as equipment efficiency and design impact on water discharge.

The expected efficiency of the turbogenerator is used as a reference to qualify various equipment suppliers by comparing the efficiency curves of their respective technological offers.

... that reveals the decision-maker industrial and business maturity

Equipment manufacturers may need to configure their turbine design parameters to secure a dedicated efficiency fit while competing on different tenders. On the standardized small hydro market, such a "one-off" technological response leads to increased non-recurring costs of engineering, longer delivery times and prevents the manufacturer from deploying a parametric approach to design with a predefined range of hydraulic profiles.

Our survey reveals, however, that small hydro purchasers are ready not to specify equipment efficiency, as long as the expected power output, availability and revenue of the power plant are secured. Efficiency calculation is normalized but the integration of expected efficiency as a purchasing criteria diverges from one acquisition to another and requires investigation prior tender submission.

Customer segmentation and behavior

Source: EY analysis

Investor requirements

Economic trade-off over time throughout the unit's lifetime: purchase, installation, operations, refurbishing, decommissioning

Efficiency profile required from the equipment to secure the business case in operating conditions and flow uncertainty

Static specification based on theoretical potential, total cost as function of plant site size and annotated site potential with prohibited maintenance frequency

1. High Static Basic
2. Medium Dynamic Imposed
3. Low Dynamic Negotiable

Source: renewablesfirst.co.uk
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For more information on how we can help you, talk to your regular EY contact or get in touch with one of our Capital and Infrastructure contacts.

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