Benchmarking of Hydropower Plants

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Declining revenues and increasing regulatory obligations require hydro operators to focus on cost performance.

Two main levers for value creation …

**Revenue Increase**
- a) Increase of production volumes through upgrades and new build
- b) Development of new 'products'
- c) Increase of energy prices

**Cost Reduction**
- a) Decrease of O&M costs

**Challenging EU market environment**
- Limited growth opportunities due to regulatory hurdles
- Uncertain market developments
- Declining market prices

**Hydropower Benchmarking**
- Identification of performance differences
- Feedback on absolute and relative cost position compared to others
Benchmarking hydroelectric power plants is a valuable method to provide insights in O&M cost performance.

**Situation and Challenge**

- Hydro plant operators are interested in gaining insights in O&M cost performance of their assets.
- A benchmark might help, however, simple KPIs such as EUR/MWh or EUR/MW are not sufficient:
  - Individual plants have different cost structures.
  - Each plant has different characteristics influencing O&M cost such as size, capacity,…

**Key Question**

What aspects does a benchmark need to consider in order to provide valuable information for plant operators and point out weak-performing plants?
There are multiple benefits for hydropower operators when participating in an external benchmarking:

**Transparency**
- Collection of cost data according to EN 13306
- Collection of technical parameters

A significant step towards data transparency in line with internal standards was observed.

**Challenge**
- Cost normalization allows for a fair comparison of the O&M cost with hundreds of hydropower plants

The project provided detailed insights in O&M cost structure and cost drivers.

**Improvement**
- A main outcome of the project is the cost gap to reach Top Quartile performance on plant and cost category level

Results will facilitate identification of improvement levers to reach Top Quartile cost performance.

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1) Operation, Routine Maintenance, Inspection, Repair, Overhaul, Modification
A high quality database and a neutral coordination are fundamental prerequisites to perform the benchmarking.

**Creation of KIP Database**

- Suggestions for possible KIPs\(^1\) and their influence by consultant and professionals
- Agreement and usage of **consistent definitions** for KIPs and O&M cost types amongst all participants according to DIN EN
- Consideration of all potential KIPs (22) for all participating plants
- Consideration of 5 (+2)\(^2\) cost types
- Consolidation of data from participants in a database via questionnaire by coordinator

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1) Key influencing parameters
2) Operation, routine maintenance, inspection, repair, overhaul (annual) have been assessed, modification (annualized) and overhaul (annualized) have been recorded but have not been included in benchmark
Non-influenceable cost drivers need to be identified, quantified and their cost influence has to be “neutralized”

- Identification of all cost drivers (KIPs\(^1\)) for all O&M cost types which
  - drive O&M cost differences between plants
  - cannot be controlled or influenced by staff

- Calculation and grading of “normalized” cost allows to directly compare “pure” performance of different plants
- Visualization of differences in performance

- Quantification of KIPs’ influence with regard to magnitude and type (linear, square-root, …)
- “Neutralizing” influence by normalizing costs

- Proper interpretation of performance
- Calculation of target cost for plants to reach top quartile
- Deriving recommendations

\(^1\) Key influencing parameters
The O&M cost comparability of different hydropower plants was ensured by comprehensive cost driver analyses.
By calculating „Normalized Cost Units“, the influence of KIPs has been „neutralized“ resulting in comparable costs

Calculation of „Normalized cost units“ (NCU) which can be compared for all different plants by dividing O&M-Costs by influence of each KIP and its weight:

\[
NCU_{OP} = \frac{Cost_{OP}}{\left( f(LWD) \times W(LWD) \right) + \ldots}
\]

- \(Cost_{OP}\): Actual Cost for Operation of specific plant
- \(f(LWD)\): Function of the KIP „Length of weirs and dams“ explaining the type influence on Operation cost
- \(w(LWD)\): Weight of KIP „Length of weirs and dams“ compared to other KIPs as result of sensitivity analysis
- \(+\ldots\): () for other identified KIPs
Scatter plots have been used to identify performance patterns of benchmarked plants.

Share of plants per quartile – Overall benchmarking result

- Ranking of all plants (Client X’s plants in red) after normalization
- Total O&M (NCU) cost compared to all plants clustered by installed capacity
- Overall performance of Client X’s plants is below average
  - 2 plants in top quartile
  - 18 plants perform below top quartile

Note: Scatter plot reflects actual results of benchmark; Selection of plants has been done randomly for visualization purposes.
Comparison – different diagrams are used for the depiction of the plant specific benchmarking results

Conclusions

- Cost performance of “plant name” is within overall mid 50%
- To reach the top quartile in all of the clusters, indicative cost gap amounts from -81 kEUR to 79 kEUR

1) Normalized currency unit (NCU) in order to compare the power plants
The Hydropower Benchmarking project provided valuable insights to E.ON

- A fair and transparent comparison of a wide range of different hydro plants across Europe could be achieved by combining statistically proven methods and expert know-how.
- The results not only identify indicative performance gaps and pinpoint their possible drivers but also provide insights on cause-effect relationships of O&M costs.
- A systematic database creation and performance assessment indicated missing information and some inconsistencies in cost allocation at participants which can now be refined.
- The analysis flagged up relations which were difficult to quantify beforehand (e.g. impact of installed capacity) and did not support other common hypotheses (e.g. impact of travel time).
- Performance differences between river groups which cannot be explained by non-influencable factors have been unveiled and point out saving potentials for the future.

Pöyry and E.ON are welcoming interested hydro operators to participate in the discussion and further development of the methodology in order to continuously drive best practice and performance improvements in the hydropower industry.
Backup
NCU allow to benchmark plant specific performance and to re-calculate target cost for low performers

- Summary of collected information
- Key influencing parameters
- Other key characteristics
- O&M cost per type

- Calculation of NCU
- Performance in the benchmark in the five O&M cost types
- Individual saving potential overall and in clusters

- Detailed results for all clusters and all cost types
Statistical analysis is used to evaluate non-influenceable cost drivers (1/2)

**Multidimensional “Problem”**

- Analysis shows that only a few factors have an influence which is actually statistically significant
  1. Installed capacity
  2. Plant size (area)
  3. Length of dams, weirs and embankments
  4. Amount of trash
  5. Age of electrical and mechanical (E&M) equipment
  6. Number of units
  7. Number of gates
  8. Number of start/stop cycles
  9. Technical complexity

**Solution**

**Relevant KIPs**

- Method used: OLS; level of significance: p>5%

1) Method used: OLS; level of significance: p>5%
Statistical analysis is used to evaluate non-influenceable cost drivers (2/2)

Non-relevant KIPs

Other plant characteristics are not identified as statistical relevant key drivers for the O&M cost level:

- Financial energy availability/availability
- Level of net generation
- Dam/weir risk class
- Quality of technical documentation
- Provision of primary control
- Travel time of operation/maintenance teams to sites

1) Method used: OLS; level of significance: p>5%
Quantification of influence is done systematically for all KIPs and all cost types

**Relationship of installed capacity and O&M cost**

- Assessment of type of influence (linear, square-root, …) has been done for all identified KIPs and all cost types
- Sensitivity Analysis has been used to appropriately consider the magnitude of influence of KPIs

**Results show:**
- **Installed capacity** is the most important cost driver
- Square root type relationship between installed capacity and most O&M cost types

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1) Fit-function as combined function with square root relationship for plants >20MW and linear relationship for plants <20MW. For O&M cost type „Inspection“: Only linear fit-function
The Benchmarking methodology was elaborated and used for more than 260 hydropower plants.

**Data collection**

**Technical data**
- Plant-specific technical parameters (KIPs)
- Range and weight of KIPs was determined by a comprehensive sensitivity analysis

<table>
<thead>
<tr>
<th>Key Influencing parameter</th>
<th>Unit</th>
<th>Operation</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant size (size)</td>
<td>m³</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Length of dam, weir and penstocks</td>
<td>m</td>
<td>13%</td>
<td>9%</td>
</tr>
<tr>
<td>Total</td>
<td>year</td>
<td>8%</td>
<td>13%</td>
</tr>
</tbody>
</table>

**Cost data**
- Plant-specific internal and external costs
- Direct O&M cost only
- Distribution according to Basic Definitions

**Benchmarking**

**Normalization factor**
- Calculation of plant-specific normalization factors using KIPs

**Cost normalization**
- Calculation of normalized, scaled cost based on the normalization factors

**Benchmarking results**
- Comparison of normalized, scaled cost per power plant with more than 260 hydropower plants
- Assignment of plants to Low, Mid or Top Quartile
- Deduction of plant-specific saving potentials

1) Key Influencing Parameter