Technical Programme | Technisches Programm

Technical benchmark for run-of-river power plants
Technischer Benchmark für Laufwasserkraftwerke

"If you're not benchmarking your performance against your competitors, you're just playing with yourself."

Al Paison

vgbe ENERGY IS US

Individual success through exchange of experience
Technical Competence Center Hydro Power

April 2025

Content

Inhalt

Cost comparison for run-of-river power plants

1. Initial situation

A cost comparison can help operators of power plants (such as hydropower operators) to maintain their competitiveness by not just relying on growth options but through the permanent improvement of their efficiency, which can be achieved primarily through optimisation. Therefore, it is essential to comprehensively understand the cost structure of operation and maintenance. However, for the comparison of the efficiency, identifying improvement potentials requires the comparability of the different conditions of power plants since the absolute costs of hydropower plants cannot be compared directly.

To conduct a sound cost performance comparison, standardized data collection is required. Until now, simple commercial KPIs such as EUR/MW or EUR/MWh have typically been used to adjust costs relative to plant size. However, this approach is of limited use in the hydropower sector, as such KPIs often fail to reflect the widely varying operating conditions, technical equipment, and structural characteristics of power plants. These structural and technical factors largely determine O&M costs—and are mostly beyond the control of management and staff.

Therefore, these parameters have to be considered by transparent and comparable assessment of the cost performance in order

Kostenvergleich für Laufwasserkraftanlagen

1. Ausgangslage

Kostenvergleiche dienen nicht nur zur Evaluierung der eigenen Effizienz und möglicher Optimierungsschritte, sondern tragen auch zum Erhalt der Wettbewerbsfähigkeit bei. Hierzu ist speziell in der vielfältigen Wasserkraft ein umfassendes Verständnis der Kostenstruktur in den Bereichen Betrieb und Wartung unerläßlich. Um hier einen Vergleich durchführen bzw. Verbesserungspotentiale herausfinden zu können, müssen bei der Erfassung der Kosten die unterschiedlichen Bedingungen verschiedener Kraftwerke vergleichbar gemacht werden.

Für eine fundierte Vergleichsanalyse der Kostenperformance ist eine standardisierte Datenerhebung erforderlich. Bisher nutzte man dafür meist einfache kaufmännische KPIs wie EUR/MW oder EUR/MWh, um Kosten zumindest an die Kraftwerksgröße anzupassen. In der Wasserkraft ist dieses Vorgehen jedoch wenig zielführend, da solche KPIs die stark variierenden Betriebsbedingungen, technischen Ausstattungen und baulichen Gegebenheiten oft nicht abbilden. Diese strukturellen und technischen Faktoren bestimmen die O&M-Kosten maßgeblich – und liegen meist außerhalb des Einflussbereichs von Management und Mitarbeitenden.

Daher sind diese Parameter in eine transparente und vergleichbare Beurteilung der Kostenperformance einzubeziehen, um to gain clear insights, which finally will result in the identification of improvement possibilities.

auch eindeutige Erkenntnisse erzielen zu können.

2. Programme

2.1. Objective

This cost comparison method was developed specifically to create a comparable basis for benchmarking operating costs. The profitability of individual run-of-river power plants is explicitly not taken into account in the analyses and survey.

In this way, only those cost items are determined in a cross-comparison that can also be influenced by the operator in accordance with national and regional differences.

2.2. Method

The cost comparison method is provided by vgbe energy. Relevant technical and infrastructural parameters were identified as cost-influencing parameters (CIP) in collaboration with experts from leading hydropower operators. Based on this, the mathematical cause-effect relationships between the CIP and individual O&M cost categories were determined. The method follows a four-step process to enable comparison of O&M costs across different run-of-river power plants (see Table 1). It serves to systematically analyze the complex interplay between cost types, cost drivers, and resulting cost performance.

2. Programm

2.1. Ziel

Ziel dieser Kostenvergleichs-Methodik ist ausschließlich eine vergleichbare Basis für die Ausgaben für Betrieb und Instandhaltung (O&M-Kostenperformance) herzustellen. Die Profitabilität der einzelnen Laufwasserkraftwerke bleibt explizit von der Betrachtung und Erhebung unberücksichtigt.

Damit werden in einem Quervergleich ausschließlich jene Kostenpositionen ermittelt, die auch vom Betreiber gemäß den nationalen und regionalen Unterschieden beeinflußbar sind.

2.2. Methodik

Die anzuwendende Kostenvergleichsmethode wird von vgbe energy bereitgestellt. Die dafür relevanten technischen und infrastrukturellen Parameter wurden gemeinsam mit Experten führender Wasserkraftbetreiber als kostenbeeinflussende Faktoren (Cost-influencing Parameters, CIP) identifiziert. Auf dieser Basis wurde der mathematische Ursache-Wirkungs-Zusammenhang zwischen den CIP und den einzelnen O&M-Kostenkategorien ermittelt. Die Methode folgt einem vierstufigen Prozess und ermöglicht den Vergleich der O&M-Kosten verschiedener Laufwasserkraftwerke (siehe Tabelle 1). Sie dient der systematischen Analyse des komplexen Zusammenspiels von Kostenarten, Kostentreibern und resultierender Kostenperformance.

Steps	I **Harmonised database**	II **Cause-effect relationships**	III **Calculation**	IV **Result generation and illustration**
Description	■ Data acquisition according to the predefined specifications: cost data as well as technical and infrastructural parameters	■ Use of determine specific CER functions: Set of statistically relevant CIPs per O&M cost category	■ Calculation of normalised, scaled cost share for every CIP and O&M cost category	■ Comprehensive and transparent overview of the O&M cost structure ■ Detailed report including best practices and a detailed evaluation for each plant

Table 1. *Four-step process to compare the O&M costs between different run-of-river power plants.*

CER … Cause-effect relationship
CIP … Cost-influencing parameter

Prozess-schritt	I **Einheitliche Datenbasis**	II **Ursache-Wirkungs-Zusammenhänge**	III **Berechnung**	IV **Ergebnis-darstellung**
Beschreibung	■ Datenerfassung gemäß den vordefinierten Spezifikationen: Kostendaten sowie technische und infrastrukturelle Parameter	■ Verwendung der definierten CER Funktionen: Satz statistisch relevanter CIPs pro O&M-Kostenkategorie	■ Berechnung der normalisierten, skalierten Kostenanteile für jeden CIP und jede O&M-Kostenkategorie	■ Umfassender und transparenter Überblick über die Betriebs- und Wartungskostenstruktur ■ Detaillierter Bericht mit Best Practices und eine Detailauswertung je Anlage

Tabelle 1: *Vierstufiger Prozess zur Erstellung der Vergleichbarkeit der Betriebs- und Instandhaltungskosten zwischen verschiedenen Laufwasserkraftwerke*

CER … Ursache-Wirkungs-Zusammenhang (Cause-effect relationship)
CIP … Kostenbeeinflussende Parameter (Cost-influencing parameter)

2.3. Results

Normalised costs serve as the basis for a multitude of evaluations in order to gain reliable and realistic insights from the cost comparison.

According to the original aim of cost comparison, the results are primarily used to provide the companies participating with a cross-comparison of the cost performance of their entire power plant fleet, of different power plant groups or individual power plants thereof.

2.3. Ergebnisse

Die normalisierten Kosten dienen als Basis für eine Vielzahl an Auswertungen, um belastbare und umsetzbare Erkenntnisse aus dem Kostenvergleich zu erzielen.

Dem ursprünglichen Ziel des Kostenvergleichs entsprechend werden die Ergebnisse primär genutzt, um den einzelnen Unternehmen einen Blick auf die Kostenperformance ihrer gesamten Kraftwerksflotte, einzelner Kraftwerksgruppen oder einzelner Kraftwerke im Quervergleich aufzuzeigen.

The results at the power plant level, i. e. for each individual power plant, are evaluated in detail, and contain, in addition to a representation of the input data, also the specific results from normalisation. Depending on the performance determined, the power plants will be assigned to the best quartile, best medium quartile, worst medium quartile and worst quartile. The performance of an individual power plant will be evaluated both in the overall comparison and within different clusters, e. g. in comparison to power plants of the same type or within (assessment limit) a river group, a company or a country.

Die Ergebnisse werden auf Kraftwerksebene, d. h. für jedes einzelne Kraftwerk, detailliert ausgewertet und beinhalten neben einer Darstellung der Eingangsdaten auch die spezifischen Resultate aus der Normalisierung. Abhängig vom Abschneiden des Kraftwerks wird dieses dem Best Quartil, Best Medium Quartil, Worst Medium Quartil und Worst Quartil zugeordnet. Die Performance des einzelnen Kraftwerks kann sowohl im Gesamtvergleich als auch innerhalb unterschiedlicher Cluster, wie etwa im Vergleich zu Kraftwerken des gleichen Typs oder innerhalb (Bewertungsgrenze) einer Flussgruppe, eines Unternehmens oder Landes, ausgewertet werden.

On this basis, the normalised costitems can be used to calculate the “re-normalised“ indicative cost difference of a power plant in comparison to the power plant of the respective cluster that is just in the top quartile. In addition to considering the total O&M costs, the evaluation will also be carried out for the individual O&M cost categories in order to be able to conduct more precise analyses of possible performance gaps.

Darauf aufbauend kann anhand der normalisierten Kostenpositionen auch die in reale Kosten „zurücknormalisierte“ indikative Kostendifferenz eines Kraftwerks im Vergleich zum gerade noch im Top Quartil befindlichen Kraftwerk des jeweiligen Clusters berechnet werden. Zusätzlich kann eine Auswertung neben einer Betrachtung der gesamten O&M-Kosten auch für die einzelnen Kostenkategorien durchgeführt werden, um detaillierte Analysen hinsichtlich möglicher Performancelücken durchführen zu können.

Ideally, the results of individual power plants are summed up within a management unit (e. g. river group) so that positive and negative indicative performance gaps are compensated for and only the netted result is used. This can make up for data inaccuracies in the cost allocation to individual hydropower plants.

Idealerweise werden die Ergebnisse einzelner Kraftwerke innerhalb einer Management-Einheit (z. B. Flussgruppe) aufsummiert, sodass sich positive und negative indikative Performancelücken kompensieren und sodass nur das saldierte Ergebnis verwendet wird. Damit lassen sich Datenungenauigkeiten bei der Kostenallokation zu einzelnen Wasserkraftwerken ausgleichen.

2.4. Benefit

Companies participating in this programme benefit from the approach in several ways.

The preparatory work itself is considered one advantage because maximum transparency is created by setting up a database for the actual benchmarking with technical and infrastructural parameters and absolute cost data, taking into account different O&M cost categories and allocations. This inevitably results in a comprehensive and detailed picture of all the facts of the plant portfolio and a complete overview of your own O&M cos structure.

While the cost comparison process provides insight into the cause-effect relationships of O&M costs, performance differences can be determined on the basis of normalised costs and possible areas for improvement can be easily identified. Last but not least, statements about indicative cost gaps compared to a top quartile wind farm can lead to improvement measures.

Analyses going beyond mere cost comparison can also be carried out in order to concretely explain performance differences. This might, for example, reveal that hydropower plant operators with slightly higher project budget expenses tend to have better Performance. This could possibly be explained by the fact that these operators limit themselves to the absolute minimum in regularly recurring operating and maintenance activities and that they increasingly counter the risks with specific measures. The results can help hydropower operators to maintain or expand the competitiveness of sustainable hydroelectric generation against

2.4. Nutzen

Die teilnehmenden Unternehmen profitieren von dieser Kostenvergleichs-Methode in mehrfacher Hinsicht.

Ein Vorteil ergibt sich bereits aus den Vorbereitungsarbeiten, da im Rahmen der Datenerhebung (technische und infrastrukturelle Parameter sowie absolute Kostendaten) durch die Zuordnung zu verschiedenen O&M-Kostenkategorien höchste Transparenz geschaffen wird. So ergeben sich zwangsläufig ein umfassendes und detailliertes Bild aller Fakten des Kraftwerksanlagenportfolios und ein vollständiger Überblick über die eigene O&M-Kostenstruktur.

Während der Kostenvergleichs-Prozess Einblicke in Ursache-Wirkungs-Zusammenhänge der O&M-Kosten gewährt, können anhand der normalisierten Kosten Performanceunterschiede ermittelt und mögliche Verbesserungsfelder identifiziert werden. Nicht zuletzt können Aussagen über indikative Kosten-Gaps gegenüber einem Top Quartil Kraftwerk zu Verbesserungsmaßnahmen führen.

Auch über den Kostenvergleich hinausgehende Analysen können durchgeführt werden, um konkrete Erklärungen für Performance Unterschiede anzugeben. Hierbei könnte sich beispielsweise zeigen, dass Wasserkraftwerksbetreiber mit leicht höheren Aufwendungen eine bessere Performance aufweisen. Dies könnte damit erklärt werden, dass diese Betreiber sich bei den regelmäßig wieder-kehrenden Betriebs- und Wartungstätig-keiten auf das absolute Minimum beschränken und vermehrt mit konkreten Maßnahmen den Risiken gezielt begegnen. Die Ergebnisse tragen dazu bei, die Wettbewerbsfähigkeit the background of current challenges.

A wide range of different hydropower plants can be compared transparently with a proven and harmonised cost comparison methodology based on expert know-how:

- Anonymised competitor positions within the cost comparison
- Detailed report including best practices and a detailed evaluation for each plant
- Determination of performance differences at the power plant level
- Identification of areas for improvement
- Statement about indicative cost targets to be able to achieve top performance
- Comprehensive and transparent overview of the O&M cost structure
- Insight into cause-effect relationships between technical and infrastructural parameters and O&M cost categories
- Indications and guide values for concrete improvement measures

von Wasserkraftbetreibern auch vor dem Hintergrund der aktuellen Herausforderungen zu erhalten bzw. zu verbessern.

Ein transparenter Vergleich einer Vielzahl verschiedener Wasserkraftwerke kann durch eine bewährte, harmonisierte Kostenvergleichs-Methode erreicht werden, die auf Expertenwissen basiert:

- Anonymisierte Wettbewerberpositionen im Kostenvergleich
- Detaillierter Bericht mit Best Practices und eine Detailauswertung je Anlage
- Ermittlung von Leistungsunterschieden auf Kraftwerksebene
- Identifizierung von Verbesserungsbereiche
- Aussage über indikative Kostenziele zur Erreichung einer Top Performance
- Umfassender und transparenter Überblick über die Betriebs- und Wartungskostenstruktur
- Einblick in Ursache-Wirkungs-Beziehungen zwischen technischen und infrastrukturellen Parametern und Betriebskostenkategorien
- Richtwerte für konkrete Verbesserungsmaßnahmen

3. Implementation

In the course of carrying out a cost comparison in a company, the following tasks arise:

- Collecting data from participating companies under strict confidentiality rules
- Validation, plausibility checks and data analyses

3. Implementierung

Im Zuge der Durchführung eines Kostenvergleiches in einem Unternehmen fallen folgende Aufgaben an:

- Sammeln von Daten der teilnehmenden Unternehmen unter Einhaltung der Vertraulichkeitsregeln
- Validierung, Plausibilitätsprüfung und Datenanalyse

- Discussion about the impact of key conclusions

Results are:

- Overview of well-performing areas and areas with improvement potential
- Outline best practices to support participants in addressing performance gaps
- Identification of improvement levers to reach top performance

- Diskussion über die Auswirkungen der wichtigsten Schlussfolgerungen

Ergebnisse sind:

- Übersicht über gut performende Bereiche und über Bereiche mit Verbesserungspotenzial
- Darstellung von Best Practices als Unterstützung für Verbesserungs-maßnahmen
- Identifizierung von Verbesserungs-hebeln zur Erreichung einer Top Performance

4. Timeline

The detailed schedule for the implementation of the cost comparison in a company is to be agreed upon individually.

4. Zeitrahmen

Der detaillierte Zeitplan zur Durchführung des Kostenvergleichs in einem Unterneh-men ist individuell zu vereinbaren.

5. Participation fee

The participation fee consists of a fixed amount of € 25,000.-- and a variable amount based on vgbe membership status and the number of run-of-river power plants to be as-sessed.

Number	Implementation fee	
Hydropower plants [-]	vgbe member [€/plant]	non-member [€/plant]
1 - 25	2,000.--	2,800.--
26 - 50	1,800.--	2,600.--
51 - …	1,600.--	2,400.--

All amounts stated are net amounts plus the value added tax.

5. Teilnahmegebühr

Die Gebühr für die Teilnahme setzt sich aus einem Fixum von 25.000,-- € und aus dem Kostenansatz, der von der Mitglieds chaft beim vgbe und von der Anzahl der zu bewertenden Laufwasserkraftwerke abhängig ist, zusammen.

Anzahl	Kostensätze	
Wasserkraft-anlagen [-]	vgbe Mitglied [€/Anlage]	Nicht-Mit-glied [€/Anlage]
1 - 25	2.000,--	2.800,--
26 - 50	1.800,--	2.600,--
51 - …	1.600,--	2.400,--

Alle angegebenen Beträge sind Netto-beträge zuzüglich der gesetzlichen Mehr-wertsteuer.

6. Confirmation of participation

Use the registration form on our website to express your interest in participating and to receive the confirmation or contract.

7. Compliance

vgbe energy, vgbe energy's contract partners related to this Technical Programme and the companies participating commit themselves to engaging in fair business practices and reject any and all forms of corruption and bribery. Based on this understanding, vgbe energy, vgbe energy's contract partners and the companies participating agree to strictly comply with their respective internal compliance rules and procedures and with statutory anti-corruption provisions. Thus, vgbe energy, vgbe energy's contract partners and the companies participating as well as their employees agree to neither offer, promise or grant, nor to demand, make, promise or accept any unjustified benefits of whatever kind in connection with the signing and performance of this contract and the resulting contractual relationship. vgbe energy, vgbe energy's contract partners and the companies participating also expect third parties involved in the performance of this contract to act accordingly and undertake to urge them to comply with relevant legal requirements.

6. Teilnahmebestätigung

Nutzen Sie das Anmeldeformular auf unserer Webseite zur Bekundung ihres Interesses an einer Teilnahme sowie zum Erhalt der Bestätigung oder des Vertrages.

7. Compliance

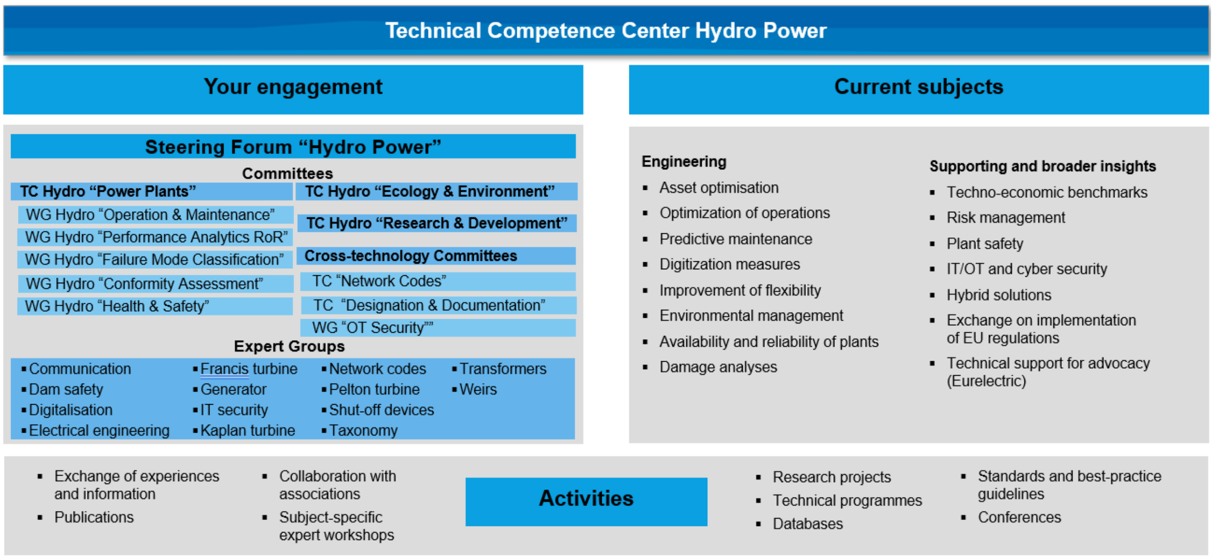
vgbe energy, die Vertragspartner von vgbe energy bezogen auf dieses Technische Programm und beteiligte Unternehmen verpflichten sich zu fairen Geschäftspraktiken und lehnen jegliche Form von Korruption und Bestechung ab. Auf der Grundlage dieses Verständnisses verpflichten sich vgbe energy, die Vertragspartner von vgbe energy und die beteiligten Unternehmen, ihre jeweiligen internen Compliance-Regeln und Compliance-Verfahren sowie die gesetzlichen Antikorruptionsvorschriften strikt einzuhalten. vgbe energy, die Vertragspartner von vgbe energy und die beteiligten Unternehmen und deren Mitarbeiter verpflichten sich daher, im Zusammenhang mit dem Abschluss und der Durchführung dieses Vertrages sowie auch des sich daraus ergebenden Vertragsverhältnisses weder unberechtigte Vorteile gleich welcher Art anzubieten, zu versprechen oder zu gewähren noch zu fordern, zu versprechen oder anzunehmen. vgbe energy, die Vertragspartner von vgbe energy und die beteiligten Unternehmen erwarten auch von Dritten, die an der Durchführung dieses Vertrages beteiligt sind, ein entsprechendes Verhalten und verpflichten sich, diese auf die Einhaltung der Gesetze hinzuweisen.

About vgbe energy

vgbe energy is the technical association of energy plant operators. Our members are companies that operate power, heat and cooling, energy storage and sector coupling plants worldwide. Currently, vgbe energy has 411 members, comprising operators, manufacturers, and institutions connected with energy engineering. The members come from 29 countries and represent an installed power generation capacity of 292,000 MW.

Technical Competence Center Hydro Power as part of vgbe energy is the first address for interested parties in techno-economic, ecological and strategic issues concerning hydropower and performs as the collective European platform and key representative for operators, manufacturers and suppliers of the hydropower community.

In this context, our hydropower community has been sharing experiences and knowledge on a high level of expertise since the year 2000. Currently, experts from 71 operating companies and 24 suppliers are actively participating in vgbe´s Technical Competence Center Hydro Power and benefit from our offers as a member of the successful hydropower network.



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Cost comparison for
run-of-river power plants
Making O&M costs between different
run-of-river power plants comparable
January 2025
ENERGY IS US


comparable costs
functions annualized
impact factor inspection
approach
database comparison
maintenance activities
overhaul multivariate
synthetic year normlisation
maintenance types
"If you're not benchmarking your performance against
your competitors, you're just playing with yourself."
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Content

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1 Initial situation

Initial situation for cost comparison of run-of-river power plants

Hydroelectric generation – it's a very mature business and cost efficiency is moving up on directors' agenda. In the past, too little importance was attached to costs, as revenues dwarfed operating costs and availability significantly affected revenues.

Costs are currently a major focus area due to their impact on safeguarding values and optimising commercial potential. Paradigm changes have changed mindsets in hydroelectric generation – reinforced by low electricity prices in Europe.

Despite the focus on cost efficiency increasing, hydro operators find it challenging to understand their own performance compared to their peers. Best practice performance is obscured due to the unique nature of each hydropower operation, which is affected by, among others, various asset types and configurations, income profile and risk, regulation, hydrological factors, climate and more.

- Leaders are reevaluating how their stations are operated and maintained at the strategic level, directly controlling the volume of work at the station level.
- Leaders are using maintenance management information systems and information-based maintenance techniques to focus the use of labour and resources.

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2 Objective and benefits

Objective

The objective of this cost-comparison method is solely needed to establish a comparable basis for O&M cost performance and is designed to systematically analyse the complex relation of O&M cost types, cost drivers and resulting cost performance.

The profitability of individual run-of-river power plants is explicitly not taken into account.

Benefits

A wide range of different run-of-river power plants can be compared transparently with a proven harmonised cost comparison method based on expert know-how:

- Detailed report including best practices and a detailed evaluation for each plant
- Identification of areas for improvement
- Statement about indicative cost targets to be able to achieve top performance
- Comprehensive and transparent overview of the O&M cost structure
- Insight into cause-effect relationships between technical and infrastructure parameters and O&M cost categories
- Indications and guide values for concrete improvement measures

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3 Structure of the cost comparison method

A multi-client cost comparison method

Scope

- Operations and maintenance costs for all run-of-river power plants should be compared.

Method

- Specifics of run-of-river power plants are considered in the cost comparison method.
- Standardised run-of-river power plants model contains all main components and is used for the cost comparison method.
- Operation and maintenance costs per main component are made comparable through a three-stage approach.

Competence

- For the development of the cost comparison method, vgbe energy relied on the competence and experience of its members.
- vgbe energy serves as neutral provider of the cost comparison.
- vgbe energy ensures absolute confidentiality of data and full transparency of information.

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3 Structure of the cost comparison method

Implementation of the harmonised cost comparison method

	Implementation of the cost comparison
Tasks	▪ Explanation of the method ▪ Introduction of a manual for data collecting ▪ Collecting data from participating companies ▪ Validation, plausibility checks and data analyses ▪ Discussion about the impact of the key conclusions
Results	▪ Overview of well-performing areas and areas with the most improvement potential ▪ Outline best practices to support participants in addressing any performance gaps identified in the cost comparison ▪ Identification of improvement levers to reach top quartile cost performance

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3 Structure of the cost comparison method

All run-of-river power plants share common main components

- Comparing run-of-river power plants is highly complex due to the nature of the plants being different in set up, geographical situation, age, technical specialities, etc.
- Regional aspects like wage level, regulation, etc. even further increase complexity.
- By decomposing the individual plants into their main components it becomes obvious though that commonalities are large – a standard plant model can be defined.
- The cost comparison builds on a harmonised methodology to normalise costs using Cost-influencing Parameters (CIPs) and the determined cause-effect relationship between CIPs and O&M cost categories.

Main components

Gates	Instrumentation and control
Weirs	Auxiliary systems
Trash rack	Turbine
Penstock	Generator
Shut-off devices	...

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3 Structure of the cost comparison method

Structure of the cost comparison method

Four-step structure to make the O&M costs between different run-of-river power plants comparable.

Steps	I	II	III	IV
	Harmonised database	**Cause-effect relationships**	**Calculation**	**Result generation and illustration**
Description	• Data acquisition according to the predefined speci-fications: cost data as well as technical and infra-structural parameters	• Use of determined specific CER functions: Set of statistically relevant CIPs per O&M cost category	• Calculation of normalised, scaled cost share for every CIP and O&M cost category	• Comprehensive and transparent overview of the O&M cost structure • Detailed report including best practices and a detailed evaluation for each plant

CIP ... Cost-influencing parameter
CER ... Cause-effect relationship

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4 Explanation of the method

Overview – Database creation

Cost data

Input cost data				
Operation	Routine Maintenance	Inspection	Repair	Overhaul

Technical and infrastructure data

Input technical and infrastructural data				
Installed capacity	Turbine type	Plant Size	Dam/Weir risk class	Trash

Data collection

The provided data are consolidated in one comprehensive database.

- Collection of provided data
  - Location data
  - Technical and infrastructure data
  - Characteristic data
  - Cost data
- Consistency and plausibility check
- Addition of specific details for different plants e.g.:
  - Location details (e.g. country and river/basin)
  - Management units (e.g. river groups)
- Basic calculations as e.g.:
  - Calculation of the parameter "age of E&M equipment" based on the average age of the plant's turbines
  - Adjustment of cost data with EUROSTAT industrial labour cost based on the assumption that 40% of the provided cost are for personnel

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4 Explanation of the method

A common understanding of terminology and definition

Cost comparison understanding of terms and definitions based on:

- **Operation**
- **Maintenance including**
  - Inspection
  - Repairing
  - Overhaul
  - Replacement
  - Modification
  - ...
- **Technical and infrastructure parameter**

VGB-S-002-02-2014-06-EN

DIN EN 13306:2018

Agreeing on a commonly accepted terminology and definition of technical and infrastructure parameters ensure the level playing field for the cost comparison of run-of-river power plants.

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4 Explanation of the method

Database creation – O&M cost categories

Maintenance activities
Inspection
Condition monitoring
Compliance test
Function check-out
Routine maintenance
Overhaul
Fault diagnosis
Fault localisation
Restoration
Repair
Temporary repair
Rebuilding
Exceptional maintenance
Maintenance task preparation
Maintenance schedule

In preparation for the cost comparison, the O&M costs at the power plant level are to be collected in accordance with the definitions according to DIN EN 13306: 2018-02. These are primarily the following five O&M cost categories:

- Op ... Operation
- Ro ... Routine Maintenance
- In ... Inspection
- Re ... Repair
- Ov ... Overhaul
- (Mo ... Modification)

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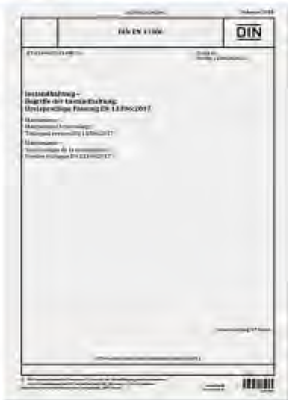

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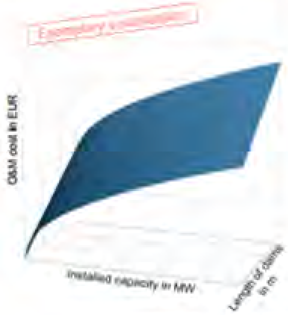
4 Explanation of the method

Multivariate regression – Statistical analyses to evaluate the cost-influenceing drivers

Multidimensional "Problem"



Solution

Statistical Analysis (Multivariate Regression)

Method used: OLS; level of significance: p > 5%
(= KQ-Method = OLS-Method
(Ordinary-Least-Squares-Method)

Relevant CIPs

The analyses show that only a few factors are cost-influencing drivers which are statistically significant.

No.	Technical and infrastructure parameter relevant as Cost-influencing Parameter (CIP)	Unit
1	Plant size (area)	[m²]
2	Installed capacity	[MW]
3	Number of turbines	[no.]
4	Number of start/stop cycles	[no./year]
5	Age of electrical and mechanical equipment	[years]
6	Number of shut-off devices	[no.]
7	Length of dams, weirs and embankments	[m]
8	Amount of trash	[t/year]
9	Technical complexity	[1(easy), 2(moderate), 3(complex)]
10	Non-CIP driven cost share	[€]

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4 Explanation of the method

Collected Database

For each hydropower plant, detailed O&M cost data and a comprehensive set of plant characteristics (technical and infrastructure parameters) have been collected and thoroughly analysed.

O&M cost data		Internal	External
Operation	Analysed cost data		
Routine maintenance			
Inspection			
Repair			
Overhaul			

A thoroughly defined logic for cost allocation has been discussed, agreed upon, documented and provided to all participants. This provides a comparable cost database for the comparison.

No.	Technical and infrastructure parameter relevant as Cost-influencing Parameter (CIP)
1	Plant size (area)
2	Installed capacity
3	Number of turbines
4	Number of start/stop cycles
5	Age of electrical and mechanical equipment
6	Number of shut-off devices
7	Length of dams, weirs and embankments
8	Amount of trash
9	Technical complexity
10	Non-CIP driven cost share

- Collection of O&M costs broken down into cost types, internal vs. external costs and annual vs. annualised costs
- Analyses of annual costs for each cost type
- Collection of annualised cost data to monitor data consistency and to evaluate the impact of spending pattern (annualised vs. annual cost) on O&M cost performance ex-post
- Collection of all potentially O&M cost-influencing plant characteristics
- Systematic assessment of plant characteristics' influence on O&M cost

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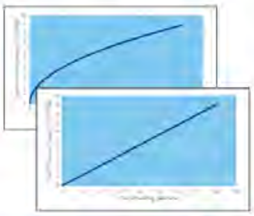
4 Explanation of the method

Systematical quantification of the cause-effect relationship between all CIPs and all cost types

CER fittings

(Assessment of type of influence (linear, square root,…))



Solution

An assessment of the type of influence (exponential, logarithmic, linear, …) has been done for all identified CIPs and all cost types. The sensitivity analyses have been used to appropriately consider the magnitude of influence of CIPs.

Results show:

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

There are cause-effect relationships between the CIPs identified as influencing costs and the individual O&M cost categories. In most cases, this was a linear function, occasionally a square root function.

	Cost-Influencing Parameter (CIP)	Op	Ro	In	Re	Ov
		Imp.	Imp.	Imp.	Imp.	Imp.
1	Plant size	8%				
2	Installed capacity	50%	50%	50%	50%	50%
3	Number of turbines	8%		13%	8%	17%
4	Number of start/stop cycles		10%	13%	8%	
5	Age of electrical and mechanical equipment	8%				
6	Number of shut-off devices			13%	8%	
7	Length of dams, weirs and embankments		10%		8%	17%
8	Amount of trash	8%	10%		8%	
9	Technical complexity	8%	10%			
10	Non-CIP driven cost share	8%	10%	13%	8%	17%
		100%	100%	100%	100%	100%

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4 Explanation of the method

Overview of the CER functions and impact factors on the specific O&M cost categories

	Cost-influencing Parameter (CIP)	Operation		Ro. Maintenance		Inspection		Repair		Overhaul	
		CER	Imp.	CER	Imp.	CER	Imp.	CER	Imp.	CER	Imp.
1	Plant size	expon.	8%								
2	Installed capacity	expon.	50%	logarith.	50%	logarith.	50%	logarith.	50%	logarith.	50%
3	Number of turbines	logarith.	8%			logarith.	13%	logarith.	8%	logarith.	17%
4	Number of start/stop cycles			logarith.	10%	logarith.	13%	logarith.	8%		
5	Age of electrical and mechanical equipment	linear	8%								
6	Number of shut-off devices					linear	13%	linear	8%		
7	Length of dams, weirs and embankments			linear	10%			linear	8%	linear	17%
8	Amount of trash	linear	8%	linear	10%			linear	8%		
9	Technical complexity	linear	8%	linear	10%						
10	Non-CIP driven cost share	linear	8%	linear	10%	linear	13%	linear	8%	linear	17%
			100%		100%		100%		100%		100%

CER functions: CER functions between the influencing CIPs and the specific O&M cost category have been determined on a statistical base.

Impact factors: The impact factors have been defined in expert interviews in order to receive the cost share of each CIP per O&M cost category.

CER … Cause-effect relationship
Imp … Impact factor respectively the defined weight of the specific Cost-influencing Parameter x (CIP) related to the specific O&M cost category xx

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4 Explanation of the method

Normalisation – Calculation of the normalised costs of a O&M cost category

$$SNC_{XX} = \frac{Cost_{XX}}{(f(CIP_X)_{XX}/f_{av}(CIP_X)_{XX})} * w(CIP_X)_{XX} + \cdots \ldots$$

SNC_{XX} … Normalised cost of the O&M cost category xx, in "Synthetically Normalised Cost" (SNC)

$Cost_{XX}$ … Cost of the O&M cost category xx of the considered power plant for the synthetic year

$f(CIP_X)_{XX}$ … CER factor of the Cost-influencing Parameter x (CIP) of the considered power plant calculated with the developed CER function between the CIP x and the O&M cost category xx

$f_{av}(CIP_X)_{XX}$ … CER factor of the Cost-influencing Parameter x (CIP) of the average power plant calculated with the developed CER function between the CIP x and the O&M cost category xx

$w(CIP_X)_{XX}$ … Defined weight of the specific Cost-influencing Parameter x (CIP) related to the specific O&M cost category xx

Indices

xx … O&M cost category
- xx: Op … Operation
- xx: Ro … Routine Maintenance
- xx: In … Inspection
- xx: Re … Repair
- xx: Ov … Overhaul

x … Cost-influencing parameter
- x: Power plant size
- x: Installed capacity
- x: Number of turbines
- x: Number of start/stop cycles
- x: Age of electrical and mechanical equipment
- x: Number of shut-off devices
- x: Length of dams, weirs and embankments
- x: Amount of trash
- x: Technical complexity
- x: Non-CIP driven cost share

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4 Explanation of the method

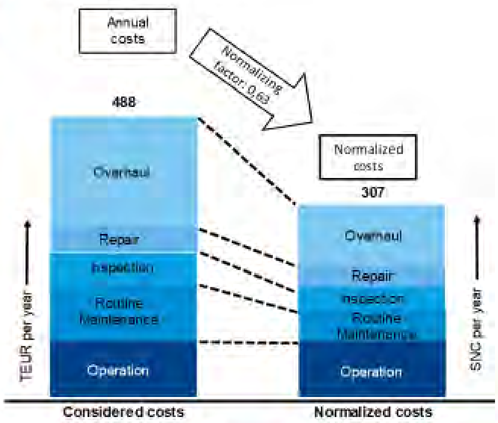
Normalisation – Calculation of the normalised cost unit of the hydropower plant

$$SNC_{HPP} = SNC_{Op} + SNC_{Ro} + SNC_{In} + SNC_{Re} + SNC_{Ov}$$

SNC_{HPP}… Synthetically normalised cost of the hydropower plant (HPP), in "Synthetically Normalised Cost" (SNC)

O&M cost category

Op … Operation
Ro … Routine Maintenance
In … Inspection
Re … Repair
Ov … Overhaul



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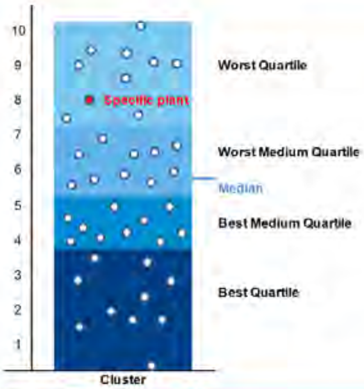
5 Example for the illustration of results

Example for the illustration of results (1)

Graphical illustration



Explanation

The "Synthetically Normalised Costs" (SNC) are compared on a plant-per-plant basis.

The plant specific performance regarding a cluster is rated by allocating grades from 0 to 10. In the respective cluster, the worst power plant receives 10 points (highest costs, worst cost performer), the best 0 points (lowest costs, best cost performer) and the points for the remaining power plants are interpolated.

The median in the cluster is the value at the midpoint of observed values, such that there is an equal probability of falling above or below.

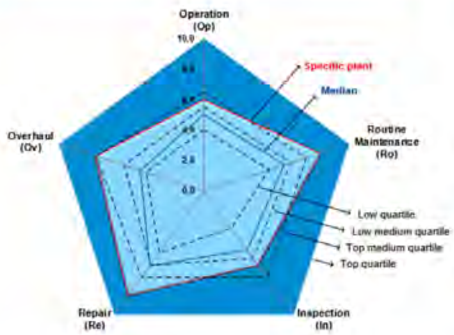
The comparison of the normalised costs can be made according to different clusters:

- Cost category
- Plant type
- Country
- Installed capacity
- River group

5 Example for the illustration of results

Example for the illustration of results (2)

Graphical illustration



Explanation

The "Synthetically Normalised Costs" (SNC) are compared on a plant-per-plant basis.

The plant-specific performance regarding a cluster (O&M cost category) is rated by allocating grades from 0 to 10. In the respective cluster, the best power plant receives 0 points, the worst 10 point and the points for the remaining power plants are interpolated. Outliers are not taken into account.

Specific plant
Performance of the specific plant compared to the overall cost comparison database.

Median
The median in the category is the value at the midpoint of observed values, such that there is an equal probability of falling above or below.

6 Advantages of companies participating

Advantages of companies participating

comparable costs
functions annualised costs
impact factor inspection operation
parameters approach influence categories
database comparison scaling
maintenance activities methodology
overhaul multivariate regression
synthetic year normlisation
maintenance types

Benefits

- Determination of performance differences at the power plant level
- Identification of areas for improvements
- Statements about indicative cost targets for achieving a top performance
- Comprehensive and transparent picture of all facts of the plant portfolio and a detailed overview of the O&M cost structure
- Insights into cause-effect relationships between technical and infrastructure parameters and O&M cost categories
- Guide values for concrete improvement measures

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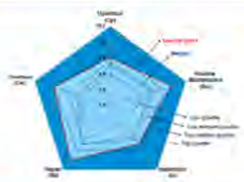
7 Organisation

vgbe energy assures behavior of trust and integrity

Confidentiality during data collection

Confidentiality in result exchange



All vgbe employees included in the multi-client cost comparison have to be especially sensitive to integrity and confidentiality of the processed data.

- Data has to be securely stored according to data protection regulations and shall not be used apart from this project.
- The external consultant will be contracted by vgbe energy and thus will follow all confidentiality rules and regulations in place.
- The multi-client comparison includes many undertakings or associations of undertakings being competitors in internal markets. Any exchange of identifiable information in between the undertakings or contact between members of the undertakings which might be incompatible with legislation on the internal market has to be made impossible by the vgbe team.

The confidentiality demanded by multi-client projects such as cost comparison is guaranteed.

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8 Prerequisite and participation fee

Prerequisite for starting

The basic prerequisite for starting the programme is that at least three companies will be committed to implement the cost comparison in their companies.

Participation fee

The participation fee for carrying out a cost comparison is composed of a fixed amount and a variable amount depending on the number of run-of-river plants and vgbe membership status.

run-of-river plants [-]	Fixum [€]	vgbe member [€/plant]	vgbe non-member [€/plant]
1 - 25	25,000.–	2,000.–	2,800.–
26 - 50		1,800.–	2,600.–
51 - …		1,600.–	2,400.–

All amounts stated are net amounts plus the value-added tax.

This means for participating companies:

run-of-river plants [-]	vgbe member [€]	vgbe non-member [€]
10	45,000.–	53,000.–
25	75,000.–	95,000.–
50	115,000.–	155,000.–
75	145,000.–	205,000.–
100	185,000.–	265,000.–
150	265,000.–	385,000.–
200	345,000.–	505,000.–

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9 Confirmation of participation

Registration

Use the registration form on our website to express your interest in participating and to receive the confirmation or contract.

- Contact data
- Number of run-of-river power plants
- Installed capacity of run-of-river power plants (from - to)

"If you're not benchmarking your performance against your competitors, you're just playing with yourself."
Al Paison

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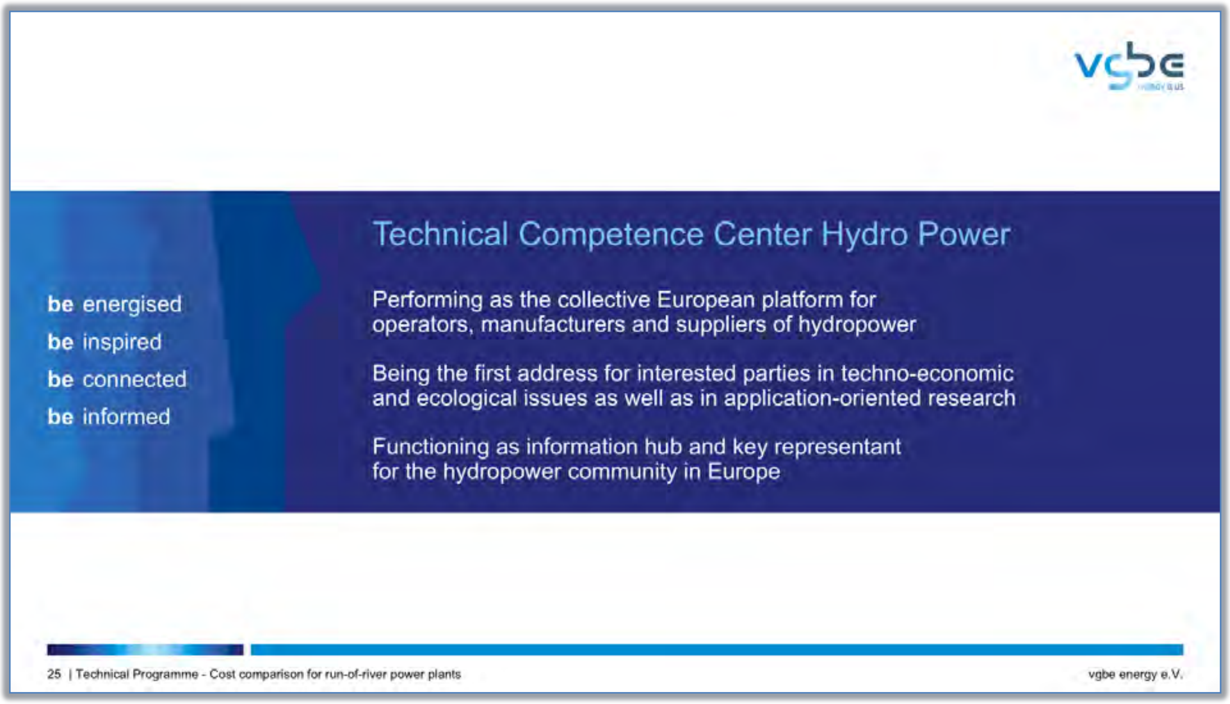
Technical Competence Center Hydro Power
be energised
be inspired
be connected
be informed
Performing as the collective European platform for operators, manufacturers and suppliers of hydropower
Being the first address for interested parties in techno-economic and ecological issues as well as in application-oriented research
Functioning as information hub and key representant for the hydropower community in Europe
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