Hydropower Solutions

HYPOSO

Hydropower solutions for developing and emerging countries

# D5.3
# Environmental and socio-economic impact assessments for 15 case studies

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857851.

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| Project no. | 857851 |
| Project acronym: | HYPOSO |
| Project title: | Hydropower solutions for developing and emerging countries |
| Call: | H2020-LC-SC3-2018-2019-2020/H2020-LC-SC3-2019-RES-IA-CSA |
| Start date of project: | 01.09.2019 |
| Duration: | 36 months |
| Deliverable title: | D5.3 (Environmental and socio-economic impact assessments for 15 case studies) |
| Due date of deliverable: | March 2023 |

Organisation name of lead contractor for this deliverable: *FN* (*05*)


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| Dissemination level | | |
|---|---|---|
| PU | Public | X |

**History**

| Version | Date | Reason | Revised by |
|---|---|---|---|
| 01 | 21/05/2023 | Draft version | FN, WIP |
| 02 | 27/06/2023 | Final version | WIP |

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**Note to Reader**: This document is based largely on existing information, and information gathered during field visits by a small team of professionals.

It is the public version of the original D5.3 document, which is available on request for eligible stakeholders (i.e., the 15 site owners, European hydropower stakeholders, and the European Commission). This public document describes the components to be considered for an environmental and socio-economic impact assessment for a pre-feasibility study. The main aim of this report is not the summary of individual data and results but the detailed description of the steps which the experts from the HYPOSO consortium consider as necessary to achieve useable results and outcomes.

In case you are interested in the original D5.3 documents, please contact:

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# 1 Introduction

HYPOSO is a multi-approach project to tackle several objectives; identification and mapping of the European hydropower industry, hydropower stakeholders in the HYPOSO target countries, education of new hydropower experts through capacity building activities and bringing together relevant actors from the EU hydropower sector with stakeholders in the target countries. Interaction with stakeholders is therefore an integral part of the activities, as workshops, capacity building activities and interviews with national/local stakeholders are envisaged in all target countries which are outside the European Union, namely workshops in Bolivia, Colombia and Ecuador in Latin America, and in Cameroon and Uganda in Africa. Additionally, capacity building courses will be carried out in Bolivia and Ecuador, and in Cameroon and Uganda.

# 2 Information about Deliverable

Within the HYPOSO project, altogether 15 different potential hydropower sites, located in five different countries (Bolivia, Colombia, and Ecuador in Latin America, and Cameroon and Uganda in Africa) have been studied, visited and further elaborated until a pre-feasibility study (15 different studies). The environmental and socio-economic impact assessment which is being dealt with in this document is a reasonable approach but cannot be taken one-on-one for permit processes. The document will allow stakeholders however to take conclusions and address potential issues early enough to avoid bad choices.
It has to be recognised, that all the projects are in a pre-feasibility phase and consequently several criteria cannot be evaluated right now. In such cases an approximation has been done according to the recent state of design and keeping in mind the potential of the project sites.

In order to better understand the sustainability check form all criteria used are shortly described:

### A1. Total energy consumption and portion of non-renewable energy

In this criterion two aspects are considered: first the energy consumption during the construction of the plant. This includes besides the construction activity itself the transports and the energy input of the building materials; secondly the energy consumption during operation, especially the portion of the non-renewable energy sources, is an important parameter. Basically, this addresses the handling of the movable parts like sliding gates, flap gates, cleaning devices as well as the transport of the debris. Constructing new plants, it is suggested to compare the total energy consumption with the life time energy production (yield factor).

### A2. Chemicals needed for operation

Toxic chemicals play an important role within the evaluation of the workplace safety and the environmental situation. This criterion addresses all ecotoxic and human toxic substances, which are needed for the operation of the plant. It must be regarded, if these substances are recycled. Important parameters in this context are the toxicity of the particular chemical, their degradability but also existing possibilities to substitute them (e.g. water lubricated bearings). Chemicals necessary for the operation are for example lubricants, (hydraulic) oils, greases etc.

### A3. Water Consumption

The water consumption in small hydro power plays a minor role. An example could be the cleaning water (during operation as well as construction). The water used for the energy conversion, is released in the original quantity and quality and hence it is not considered as water consumption.

### A4. Emissions into the compartments water, air and soil

This part names all emissions, caused by the construction and operation of the plant as well as transport, into the different environmental compartments. Attention must be paid as well to the total amount of emissions as to the single substances. Counted among the evaluated emissions are: gaseous emissions (e.g. $CO_2$, $NO_x$ …), waste water and sound emissions (squeal of the rack, hum of the generator etc.) and vibrations (structure-born noise of the turbine, the generator etc.). In addition, impacts, caused by oils and greases, coming from moveable parts, which are in contact with water, may occur.

### A5. Waste, particularly hazardous waste and its treatment

Included are all biogenic and non-biogenic wastes from cleaning processes like e.g. trash racks (coarse and fine), sediment trap etc. and also substances coming from maintenance such as gearbox or transformer oils. Single conglomerates (mixture of materials with different origin and quality, that is hard to separate) contain both organic and mineral substances and hence they are difficult to standardize. The amount and the composition of the trash rack material depend on the state of the water body but also on the utilization of the catchment area (agriculture, forestry, settlements…). The latter are technically hard to affect. So, the management of the trash rack material is evaluated.

Possibilities for the further treatment of waste and other accumulating materials are the storage in intermediate disposal respectively the disposal in final disposals or also the further utilization of the material (composting of biogenic matter, agricultural use of reservoir sediments).

### A6. Tolerance towards technical failure

Tolerance towards failure is the ability of an operating system to work also properly under divergent operating conditions. These divergent conditions may occur due to technical as well as natural reasons. Moreover, errors may happen because of incorrect manipulation.

In this context the following technical incidents are cited as an example: the runaway of the turbine and the generator in case of grid failure, dam collapse, collapse respectively damage of constructions, alternation of natural basic conditions like floods, earthquakes etc. and also measure for human security.
The content of this criterion are precautions, which are set against possible incidents respectively extraordinary operating conditions like floods, ice jams, draughts etc. as well as precautions against incidents not exactly estimable means general precautions according to the precautionary principle. In this case quantitative statement are not possible. The question about the consideration of precaution measures in the plant concept can just be answered with Yes or No as well as the question about the availability of information about the tolerance towards failure.

### A7. Waterproofing the ground due to construction works and roads

Here the space required for the plant and also for transport routes is mentioned. Waterproofing areas cause different problems. Land surface represents a limited resource and cannot be increased artificially. On waterproofed surfaces it is not possible for rain and surface waters to infiltrate and the regeneration of the ground water is disturbed. The natural functions of the ground are restricted; sometimes areas of unspoiled nature are cut through. Also, in terms of the "postulate of equity" waterproofing the ground means that for today's community the possibilities of land use and nature are more and more confined. The range of the limited resource gets less and less and following generations will have on the one hand less available area and ground and on the other hand insufficient possibilities to rehabilitate and restore waterproofed land into fully functioning ground and hence they will experience restrictions in their options and liberties.

### A8. Inundation and flood protection

Floods are natural events, which cannot be avoided. They form the landscape and the living space of man since ever. Dealing with floods as interdisciplinary approach is important, especially a trade-off of the land use planning measures and building regulations for the needs of flood protection. Depending on the local circumstances should be ensured as well the protection against floods (ecosystems and housing areas which are situated close to rivers or in their sphere of influence) as the ecologically necessary inundation (floodplain forests etc.), in order to preserve the population and evolution of the flora and fauna. The preservation or creation of floodplain areas is an equal goal in ecology and water management and refers to areas, that have been already flooded or areas, where the inundation does not signify a restriction of the land use of man.

### A9. River morphology and flora

Rivers transport sediments from bank slopes and terraces of floodplain forests und they are responsible for the variability in time of the riverbed. Variable river widths, structural elements (groynes, rocks etc.), an improvement of the shading of the river but also the removal of absolutely stable fixation measures like plaster etc. can lead to morphological changes. This criterion includes all measures aiming at the restoration of the dynamic processes of the water and sediment regime such as erosion, sedimentation, and inundation etc. of the affected water body. Furthermore, all provisions are addressed, that are needed for the restoration respectively conservation of the ecosystems along the embankment areas.

### A10. Safeguarding the river continuum

There is a differentiation made between temporal (discontinuities in the course of the year) and spatial continuum. At storage power plants the problem of surging occurs. The quick rising and decreasing release of water from reservoirs causes artificial fluctuation in flow on a daily or weekly rhythm. In fact, this is of inferior importance in small hydro power.
In case of diversion schemes there is the discussion about an appropriate residual flow in the diversion reach. This criterion includes all measures that guarantee the survival of aquatic life (like fish population, benthos etc.). Measures concerning fish passes (in order to bridge height gaps) and/or obligatory residual flow can be carried out.

### A11. Protection of groundwater

Hence the groundwater must be protected not just from pollution (qualitatively) but also from overexploitation (quantitatively). In the headwater area an increase of the groundwater level due to infiltration may occur (permeation of headwater into the groundwater body). In the tailwater area an exfiltration due to excavation may occur and lead finally to a decrease of the groundwater level. An increase of the groundwater level can lead to water logging in agricultural areas; a decrease can lead to a run dry of wells. In addition, the infiltration in the headwater can cause not just quantitative change but also a qualitative change because of the usually higher pollution of the river water. In order to avoid as well quantitative as qualitative changes of the groundwater sealing devices can be set along the banks.

### A12. Safety at work

As already mentioned at the point “tolerance towards failure”, divergent operating conditions may happen due to operating errors. Within this topic the probability of accidents in the whole area of the plant is meant, caused by inattention or ignorance of the employees putting them into a hazardous situation. Preventions according to the precautionary principle are important. The availability of measures will be evaluated (Yes / No)” such as:

- Keeping safety distance to conducting parts
- Cover sheets or grids at rotating parts
- Railings in outside areas
- Exit structures in waterways
- Limited access to sensitive areas
- Wearing of safety goggles, ear protection, security boots etc.

Differentiations referring to the probability of accidents and the individuality of the plant can be discussed.

### B1. Quality of employment

In this point the stress of the employees at their working place in the plant is addressed. That means that mental stress like long-lasting concentration, time pressure or other stress factors such as physical work or long-time standing, must not reach an extent, that hinders the affected persons to live their schemes of life beyond working life. Quantitative indications concerning this point are difficult to be defined. Even the easy Yes – No –answer does not seem possible here. Moreover, the kind of answer depends on the moment of asking this question. Before starting the operation of a plant, it may be difficult to make any evaluation. In addition, the evaluation depends on the subjective feeling of the employees. Hence it is suggested to clarify these questions in a discourse.

### B2. Safeguarding and creating qualified jobs

Within regional development plans also the creation of new jobs is an important issue. Emphasis is put on the necessity of specific knowledge and associated qualification. According to experience the potential of creation of jobs directly can be estimated as low at small hydro power plants (see B3). The settling of new companies and the involvement of regional existing companies in the phase of construction or maintenance of the plant may have indirect effects on job positions which hence remain preserved in the region and can therefore reduce rural depopulation.

For security reasons the service staff should be able to arrive at the plant within half an hour. This is equal to a distance of 10 to 30 km, depending on accessibility to the plant. A possible special case would be the creation or preservation of jobs by locating a small or medium sized enterprise that uses directly the energy produced by the small hydro power plant. This can be an advantage if the power supply occurs at low voltage. Then the production costs arising from the own plant are lower than the delivery costs from the grid.

### B3. Gender aspects (equal treatment)

The issue of this point is the equal treatment concerning gender and age. Anyway, in small hydro power usually just one or two employees are needed for a plant. Often the plant is run by the operator him- or herself. More important in this criterion is for example the preference of suppliers and construction companies which basically regard the equal treatment of their employees.

### C1. Documentation/application/transfer of existing know how

Hydro power is used already since ancient times. Therefore, a huge amount of knowledge and experience exists. This know-how covers two subject areas: on the one hand the technical know-how, which is available for the public by means of publications (documentations of existing plants), information events and guided tours and so it will be preserved also for future generations. The traditional know-how can support the development of innovations respectively it can be used and documented in combination with new applications.

Furthermore, these experiences can be exchanged in hydro power forums. On the other hand, interdisciplinary know-how of residents, fishers, biologists and geologists about local circumstances (expert knowledge) may be integrated in the engineering of a small hydro power plant such as:

- Fish population
- Fish stocking measures
- Flood levels
- Conservation respectively influencing floodplain forests
- Soil characteristics – geological structure

### C2. Need for additional qualification and workforce in the plant

The issues in this point are unlike point B3 the qualification respectively the possibilities of (further) continuing education of single persons, especially educational possibilities and their financing. Training and (further) continuing education are determinant for future life. Insufficient respectively missing training is the main reason for unemployment and risk of poverty. Operators of single plants rely mostly on already skilled workers. Operators who run several plants should consider measures for (further) continuing education for their employees.

### C3. Accompanying research during operation of plant

Long term research projects in the fields of environment and technology are prerequisites for real innovations and further development. Hence it is important to create capacities for accompanying research within the operation of a plant. The extension of interdisciplinary research is an important issue. It might be easier for operators of several plants to have their own research capacities. Apart from that also the participation on research projects may be evaluated.
Moreover, the creation of capabilities may also occur through monitoring in the ecological and technical field. Examples are:

- Innovations and further development at fish passes
- Finger-shaped adjustment of the bars of Tyrolean intakes
- Ceramic coating of the turbine shaft to protect from corrosion by static electricity

### D1. Support of regional infrastructure

The operation of a plant may produce economical impulses, which offer possibilities to secure livelihood to the people and consequently reduce or prevent rural depopulation. Service, supply but also social infrastructures like families keep maintained. In terms of the "postulate of equity" the freedom to choose should be conserved for future generations. Supporting the regional infrastructure does not only have direct effects like power supply in order to support the local grid and road constructions such as access roads. If (see also B2) also positive effects for the job availability occur, tendencies to rural depopulation can be reduced and also the social infrastructure like family as well service and supply infrastructure, like post office, grocery shop or medical supply, keep maintained.

### D2. Remaining regional profits

The goal of an economic strategy on local and regional base is to satisfy a predominant or at least big amount of the regional demand for goods and services by regional manpower using regional resources. Therefore, a bigger amount of the regional income will circulate locally instead of flowing off of the region. While constructing, maintaining and repairing a plant different business such as electricians, mechanics or constructing companies participate. These may come from the region or from the further surroundings. If they come from the region, the regional added value can be strengthened.

### D3. Conservation of the cultural landscape / man-made environment as good to be protected

Every construction activity has effects on the natural scenery. The matter here is to pay attention to aesthetics, harmony and the use of materials locally available.

### E1. Participation of parties concerned during licensing and operation

Participation is an important point in the concept of sustainability. The issue here is the participation of the affected persons in the decision-making processes.
Due to different ways of participation like public involvement procedures or focus groups it is possible to ensure a voice of affected persons in decisions. Task of such procedures is to collect expectations, needs and concerns of the affected ones. In such a way different interests of the various stakeholders may be detected and respected respectively balanced. Important is the transparency of the involvement procedure for all stakeholders.

### E2. Creation of social resources

A so-called "community-feeling" forms an important basis for the "social capital". Following examples enable a strengthening of the community:

- Painting/decorating the small hydro power plant together
- Additional attractions like exhibitions in the powerhouse organised by residents
- Battery loading for free
- Design of an information path in the plant terrain
- Opening ceremony after completion, days of public visit

### E3. Multifunctionality of the plant

In connection with the multifunctionality the following cases need to be distinguished:

1. Power production is the primary use of the water body
2. Power production is just a complementary secondary utilisation next other kind of water utilisation

The possibility to assure multifunctionality depends strongly on the way of operating the power plant (storage power plant / run-of-river power plant, diversion power plant / weir power plant).
In case 1 (primary power production) secondary benefits could be achieved such as:

- Heating of nearby swimming ponds by generator cooling
- loading stations for private electro vehicles
- Creation of biotopes in the backwater area
- Creation of leisure areas

Following examples include utilisations of various kinds and power production is a complementary utilisation:

- Power plants integrated in water supply systems
- Power plants integrated in sewage systems
- Exploitation of available heads in existing irrigation canals for power production

#### F1. Several indicators describing the profitability of the plant

A fundamental requirement for the formation but also for the existence of a business is its (predicted) profitability. The application of the best available technologies brings an increase in the efficiency of resources but their use itself does not guarantee a sustainable economy as the achieved savings may be compensated by the higher total cost. It is the aim in the development to render the construction respectively the operation of the schemes as independent as possible from subventions. That means that it is important to keep an eye on the profitability of the scheme already from the very beginning. For the evaluation of the profitability of a productive enterprise different indicator are available. Which indicators are taken into consideration for the evaluation has to be chosen according to data available at the moment of the evaluation. Possible debts must consider the liberty of acting and choosing of future generations.

#### G1. Effective use of water as a resource

In terms of sustainability an optimal use of water as a natural resource is required. In order to safeguard a sustainable management of water as a resource it is needed to aim for a high efficiency in technical terms or, in other words, high technical conversion degrees. This criterion covers all measures that allow an optimal use of water as a resource. The hydraulic design of a scheme is based on the optimization of the parameters head and discharge. Based on the optimized discharge the maximal effective use of the water body has to be carried out.

# 3 Impacts and Sustainability check

The implementation of a Small Hydro Power Plant has different possible impacts, beneficial ones as well as unwanted impacts. Mitigation measures are nowadays known and should be considered.

## 3.1 Possible beneficial impacts

- Renewable energy production
- Work places during construction
- Work places during operation

- Improvement of infrastructure (roads)
- Construction works (dam) as touristic attraction
- Construction of bridges
- Creation of a water reservoir
  - Improvement of water availability for local population
  - Improvement of fisheries, eventually fish farming
  - Initiating touristic development
- Stabilising the electrical grid in the village/area around
- Industrial water supply for local population along water conveyance structures
- Reactivation and strengthening of fishing activities along the river
- Usage of already existing electricity evacuation lines minimising impacts
- Completing already existing electrical grid structure
- Improvement of already existing artificial lakes upstream the weir
- Installation of common cloth washing places

## 3.2 Possible unwanted impacts

- Alteration of existing river habitat due to flow reduction
- Interruption of river continuity at the weir
- Alteration of flow conditions downstream due to short term storage operation

## 3.3 Possible mitigation measures

- Erection of a fish lift to ensure river continuity
- Limitation of water level variation due to storage operation
- Fixation of ecological flow in the diversion reach

## 3.4 Sustainability check

Traditionally any sustainability check is applied on existing and operational structures but not in the stage of a pre-feasibility study. Nevertheless, such an early-stage check will uncover weaknesses and critical elements. It will give some orientation where to put special emphasis and efforts in order to allow for the best possible solution. The recent evaluation is based on probabilities and experience instead of hard facts. A similar evaluation should be performed after implementation of the project and further on in regular time intervals to safeguard correct operation and further on improvement where recommended.

The following table is just an example on how the evaluation could be done in a clearly arranged way.

| Name of the plant | Mean flow (m³/s) | Evaluator |
|---|---|---|
| | | |
| Type of the plant | Rated discharge (m³/s) | Date |
| **in-river, run-off/storage** | | |
| River | Rated head (m) | Comments |
| | | |

| Category: Name | Category: Value Categories | Cluster: Name | Cluster: Value Cluster | Criteria: Code | Criteria: Name | Criteria: Value Criteria | Indicators: Name | Evaluation: not applicable | Evaluation: 4 excellent | Evaluation: 3 good | Evaluation: 2 poor | Evaluation: 1 very poor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A Impacts concerning health and environment | 3,35 | Input | 3,67 | A1 | Total energy consumption and portion of non RE | 3,00 | Energy yield factor | | 4 | | | |
| | | | | | | | Energy demand for transport purpose [l/km] | | | | 2 | |
| | | | | A2 | Chemicals needed for operation | 4,00 | Toxicity of chemicals [LD 50] | | 4 | | | |
| | | | | | | | Chemicals are biodegradeable [yes/no] | | 4 | | | |
| | | | | | | | Chemicals to be substituted [yes/no] | x | | | | |
| | | | | A3 | Water consumption | 4,00 | Amount of water [l/a] | | 4 | | | |
| | | | | | | | Kind of water [ground-/drink-/industrial water] | | 4 | | | |
| | | Output | 3,42 | A4 | Emissions towards the compartments water, air and soil | 3,33 | Spezific emissions [mg/MWh] | | 4 | | | |
| | | | | | | | Intensity of sound emmissions [dB] | | | 3 | | |
| | | | | | | | Measures of sound insulation [yes/no] | | | 3 | | |
| | | | | A5 | Waste, particularly hazardous waste and its treatment | 3,50 | Kind of disposal [waterproof yes/no] | | 4 | | | |
| | | | | | | | Specific amount of waste [l oil/MWh*a] | | | 3 | | |
| | | Risks | 3,00 | A6 | Tolerance towards failure (technically) | 3,00 | Precautionary measures [yes/no] | | | 3 | | |
| | | Area | 3,50 | A7 | Waterproofing the ground due to construction works and roads | 4,00 | Specific area [m²/MWh] | | 4 | | | |
| | | | | A8 | Inundation and flood protection | 3,00 | Degree of flood protection [a] | | 4 | | | |
| | | | | | | | Flooded area [m²] | | | | 2 | |
| | | Waterbody | 3,17 | A9 | Rivermorphology and flora | 3,00 | Measures [yes/no] | | | 3 | | |
| | | | | A10 | Safeguarding the river continuum | 3,50 | Amount and duration of delievery [% von MQ] | | 4 | | | |
| | | | | | | | Functioning bypass system [yes/no] | | | 3 | | |
| | | | | A11 | Protection of groundwater | 3,00 | Alteration of groundwater level [m] | | | 3 | | |
| | | | | | | | Alteration of groundwater quality [increase/decrease] | x | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| B Safeguarding and quality of work | 3,67 | Plant | 4,00 | B1 | Safety at work | 4,00 | Measures of precaution [yes/no] | | 4 | | | |
| | | | | | | | Accidents/a [number] | x | | | | |
| | | | | | | | Reason for accident [discourse] | x | | | | |
| | | | | | | | Kind of accident [discourse] | x | | | | |
| | | Actors | 3,33 | B2 | Quality of employment | 4,00 | Working conditions and -hours [discourse] | | 4 | | | |
| | | | | B3 | Safeguarding and creating qualified jobs | 3,00 | Qualifications necessary [operator] | | | 3 | | |
| | | | | | | | Regional manufacturing firm [yes/no] | | | 3 | | |
| | | | | B4 | Gender aspects | 3,00 | Equal treatment [yes/no] | | | 3 | | |
| C Know how | 2,54 | Existing resources | 2,33 | C1 | Documentation / application / transfer of existing know how | 2,33 | Documentation [yes/no resp. much/few] | | | 3 | | |
| | | | | | | | Using the results of documentation [yes/no or much/few] | | | | 2 | |
| | | | | | | | Transfer [yes/no] | | | | 2 | |
| | | Resources to be created | 2,75 | C2 | Need for additional qualification of workforce in the plant | 3,50 | Necessity of additional qualification [yes/no] | | | 3 | | |
| | | | | | | | Possibilities for further education [yes/no] | | 4 | | | |
| | | | | C3 | Accompanying research during operation of the plant | 2,00 | Monitoring concepts [yes/no] | | | | 2 | |
| | | | | | | | R&D portion [compared to turnover in %] | | | | 2 | |
| D Regional development | 2,00 | Regional economy and provision | 2,50 | D1 | Support of regional infrastructure | 3,00 | Extension of traffic network with common profit [yes/no] | | | | 2 | |
| | | | | | | | Extension of electrical grid with common profit [yes/no] | | 4 | | | |
| | | | | D2 | Remaining regional profits | 2,00 | Portion of total investment remainig in the region [%] | | | | 2 | |
| | | Cultural and individual identity | 1,50 | D3 | Conservation of the cultural landscape as good to be protected | 1,50 | Involvement of (landscape) architects [yes/no] | | | | | 1 |
| | | | | | | | Consideration of characteristic regional design [yes/no] | | | | 2 | |
| E Stakeholders interaction | 3,00 | Stakeholder interactions | 3,00 | E1 | Participation of parties concerned during licensing and operation | 4,00 | Transparent participation process [yes/no] | | 4 | | | |
| | | | | E2 | Creation of social resources | 4,00 | measures [yes/no] | | 4 | | | |
| | | | | E3 | Multifunctionality of the plant | 1,00 | measures [yes/no] | | | | | 1 |
| F Profitability | 3,00 | profitability of the plant | 3,00 | F1 | Diverse Indicators for the profitability of the plant | 3,00 | Payback period [a] | | | 3 | | |
| | | | | | | | Specific investment [€/kWh oder €/kW] | | | 3 | | |
| G Technical concerns | 4,00 | technical efficiency | 4,00 | G1 | Effective use of water as a resource | 4,00 | Efficiency of the plant [%] | | 4 | | | |
| | | | | | | | Hydraulic losses [% of total head] | | 4 | | | |