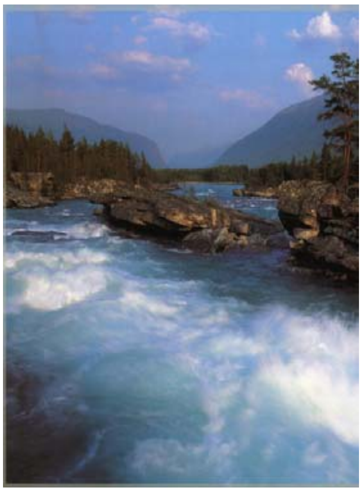
SMALL DECENTRALIZED HYDROPOWER STATIONS A FUTURE FOR RURAL AREAS WITHOUT DIESEL POWER

The above headline has intentionally been written without punctuation marks: The author is conscious of the fact that there are regions in Rural Areas where the available hydro potential is not sufficient for covering effectively the energy requirements by mini hydro stations. With the present essay the role of mini hydro will be outlined, particularly destined for the reliable decentralized supply, and reference be made to this option as far as the same is not yet known. On the other hand it needs to emphasize the difference between large-scaled hydro and its smaller brothers and sisters. This will prevent mini power stations from being "planned to death" by approaches suitable only for large-scaled hydro.

The most essential aspects dealt with by the present essay are the following:



1. **Benefit of Mini Hydro for Rural Area**
   - **1.1 Political Aspects**
   - **1.2 Reflections on Environmental Protection**
   - **1.3 Service**

2. **Basic Features of a Decentralized Energy Production**

3. **Possible Solutions**
   - **3.1 Ossberger Concept**
   - **3.2 Ossberger® Turbine**

4. **Example of Investment**
   - **4.1 Investment Cost**
   - **4.2 Proceeds**

1. Benefit of Mini Hydro for Rural Areas

The availability of a reliable energy production in rural villages makes a difference like between day and night: Upon nightfall this becomes clearly evident as in one case all life breaks down, and in the other one continues in the light of street lamps and incandescent bulbs.

1.1 Political Aspects

Following basic requirements = Energy =

Advantageous for women (pumps, light, cooling)

Preservation of tropical rain forests

Destined for the rural population

So there are good reasons for considering the availability and the energy price as a scale for valuing the prosperity of a State. Our world is filled with facilities that absolutely require electric energy. For this reason the term of energy was added to the catalogue of **basic requirements**.

The basic requirements of each inhabitant should be covered reliably and at reasonable costs. If the energy demands which exist in rural areas need to be fulfilled good solutions are required, which apart from reliability can effectively be afforded. A solution with permanently high operational costs as e.g. faced with Diesel units will create a permanent fuel supply problem, so there will only be a weak basis for the provision of energy.

In all cultures the role of men and women has been marked by a long tradition. In most cultures women provide food and neat clothing for their families. The means which are available to women to comply with these tasks will decide on whether the conditions are **advantageous for women** or not. Reliable energy at favorable costs will drive pumps, by thus making superfluous the daily work of carrying water. Lighting will create the basis for a good general formation, as school children may do reading and writing exercises in the evening. Finally the support of food provision is of decisive importance. This concerns the provision of electric energy for cooking and the possibility of keeping
food hygienically in store by using refrigerators.

The **preservation of tropical rain forests** or of the vegetation by using an energy carrier like water becomes evident if the utilization of electric energy is considered as an alternative to the cooking-pot heated by wood or charcoal fire.

A reliable energy supply in a remote area where the residents do not have good prospects for the future offers an alternative to the emigration to slums of big cities. Examples in various regions of Africa, Latino-America and Asia have shown that the reliable energy supply **destined for the rural population** created a basis for the future. Slowly but steadily small craftsmen's' stores came into existence. In the course of time confidence increased, by thus permitting some long-term planning. Possibly developments of such kind may even set on foot a return of emigrants, at least of the first generation, to their home villages.

Efficient politics aiming at the development of a remote region or rural area is unthinkable without reliable energy supply.

1.2 Idea of Environmental Preservation:

- Regenerative energy
- No consumption of resources
- No emission (Co_2)
- Improved water quality

Meanwhile even countries with high oil, gas and coal resources have recognized the advantage of **renewable energy carriers**. Oil exporters may face, with the utilization of domestic renewable energy, the possibility of exporting more fossil energy carriers. Countries importing fossil energy carriers even profit by more benefits. Apart from a remarkable relief of the imported volume no costs will become due for storage and transport. Renewable energy carriers are available in the country itself, normally quite close to the consumption centers. This even holds true for mini hydro at a much higher extent than for large-scaled power units.

On discussing renewable energies the fact is frequentl overlooked that the energy carrier water is not consumed, but utilized only. Supposing a corresponding geography it is available for further hydro stations. In other cases mini hydro stations will utilize the energy potential in irrigation systems, always keeping the fact in mind that **no resources are consumed**.
This also results in an **emission-free** energy production. In Rural Areas this point will surely not be so much considered than in densely populated and industrialized countries.

This also applies to the further "environmental argument", i.e. the **improvement of the water quality** by Ossberger® Turbines. Even though the fact is essential that for protecting the turbine the screen will collect all debris contained in the water, and that the water is enriched with oxygen during energy production. In Central Europe the best trouts are found in the turbine outflow section.

1.3 Service:

- Low investment costs
- Long life expectancy
- Simple servicing
- Low operating costs

As far as mini hydro can be implemented in the form of small-scaled units instead of small versions of large-scaled plants the same are advantageous for their **low investment costs**. Some figures are available as examples from the past few years. So small hydro stations were set on foot in the classical style of large-scaled ones at costs of > 10.000 $/kW. Hydro stations which follow the Ossberger Concept demand investments of between 2,500 and 3,500 $/kW. With this kind of energy production it will be essential to minimize the investment costs, as the provision of funds will be indispensable for utilizing hydro power.

This goes along with the advantage of a **long life expectancy**. Here decades of service need to be considered. If after some decades expenses become necessary for refurbishment the service may even be maintained by these costs for some further decades. The long life is one factor for the effectiveness of the efforts spent on the development of a region. Some few spare parts only, mostly available in the country itself, will thus guarantee a good future for a region.

Once again we need to make reference to the difference between special mini hydro and small power stations based on the technology of large-scaled ones. Typical mini hydro power stations which follow the Ossberger Concept only demand a simple maintenance. The **simple servicing** permits a reliable functioning even under the supervision of laymen. Numerous examples in all parts of Africa are giving proof thereof.

These correlations will finally focus on the decisive point: **Low operating costs**. Above all the fact is essential here that no sequential costs need to be faced for fuel. The ”fuel” water, ”white coal”, will be available free of charge and without costs of transport for the permanent circulation of evaporation and rainfall.

To sum up the topics the benefit of mini hydro for Rural Areas is beyond any doubt. So please permit us to reflect on the basic features of a decentralized energy production.

2. Basic Features of a Decentralized Energy Production

The Availability and Supply of Energy in the ”Open Country”

The supply of power to large conurbations or industrial centers will not be discussed here. This has its own rules, which apply both for industrial and developing countries. It is, however, important to recognize that the supply of power to such centers is basically quite different to that in the ”open country”.

Initial Position in the Rural Development Area

For the rural development area, the following initial position exists in general:

- There are, to be sure, many future consumers scattered over wide areas, but only in very small groupings.
- Even when electrical power can be made available, only very small consumption is to be expected over long periods.
- No one can forecast which of the many small centers will later achieve economic importance and which will lag behind in development.

Conditions for Profitability of a Rural Power Supply

While in conurbations the form of power supply can be exactly planned and selected with great certainty, starting from the power demand, the existing power sources or those to be provided and their position with respect to the center of consumption, so that profitability forecasts finally become reality, in rural development areas, because of the facts stated above by topics a.) to c.) no profitability figures can be calculated in the planning stage or finally reached, if one wished to approach the electrification of this area in the same way to which one is accustomed for conurbations.

Cost Allocation of the Price of Current

Just as, in Europe, for example, one does not start by building a base load power station in the Northern part of Germany for the supply of power to the villages in Austria (this is a comparable situation to illustrate the point), this is even more impracticable in the typical development area. Since the costs of current are made up from generation, transmission and distribution costs, while as a rule the transmission and distribution costs exceed the generation costs (in Europe in general by more than twice), this fact alone prohibits the supply to tiny, widely separated and scattered groups of consumers of unknown order of magnitude by the erection of a central power station feeding into a system with an infinite number of branches.

Technical Handicaps

Quite apart from the capital cost of such a system, the technical problems (transmission losses, voltage drop, routine maintenance of the system) make this form of power supply, allowing for continuous operation, an expensive solution and one liable to faults. The many mains failures and power cuts in the overland systems of developing countries (and even in many European countries) confirm this finding.

Reliability

Finally, the lack of reliability which is offered by a central power station must be mentioned as a significant disadvantage, if this has to supply enormous areas on its own. Once the economic development of a country or region is mainly dependent on electrical power, a permanent electrical supply must be ensured, since otherwise it does more harm than good. A central power station, which supplies a whole region, together with the weak points of a non-interconnected supply system, is a dangerous factor of uncertainty from the point of view of the national economy.

Build up of a Rural Power Supply

The financial and economic factors described thus favor the decentralized establishment of power stations.

Establishment of the First Oases

The healthy development of such a power generation and supply system for rural areas thus appears as follows:

- Places which have some importance and density of population and where a further economic development can be expected, will be supplied with electrical power by a small plant operating as an isolated unit. The costs are low and do not form a misplaced investment, even if the development of the locality does not proceed as expected.
- If the demand for power grows unusually, then, by means of the reliable growth data which is available from practice, it is possible, at that time, to determine with a high degree of certainty, the order or magnitude by which the power generation capacity must be extended.
- Several neighboring isolated power stations form the start for the future interconnected operation.
- With increasing demand, small interconnected systems can be connected to, or joined up to form, large central systems, while the local power stations retain the important tasks of local generation,

reduction of transmission losses and voltage boosting. Thus they do not become redundant but increase the reliability of the interconnected system, in its final state, to a quite extraordinary extent.

Especially when setting up the first island units, the choice of the kind of generator unit is of great importance. It should be arrived from the following points of view:

- Low capital costs and above all low operating costs in continuous service.
- Simple erection, assembly and commissioning
- Simplicity of attendance, care and maintenance with the technical facilities and personnel available in the developing country.

3. Possible Solutions

3.1 Ossberger Concept

On the basis of numerous experiences made with non-governmental organizations as well as private investors OSSBERGER worked out a concept concerning the realization of typical small hydro power stations for the decentralized supply of electric energy in developing countries with the participation and active co-operation of the regional governmental Electricity Boards.

The **concept** is based on long-year practical findings and experiences and may be resumed to 5 theses.

(1) The locally available personnel of the competent authorities for the generation and distribution of electric energy can, farly, find out the characteristics by themselves which are required for the project work with their own skill and possibilities if the European partner's questions are clear enough.

The remark should be made that particularly for the project work for small hydro power stations exaggerated demands should not be made in this respect. At the first stage the diligent determination of the existing head and flow rate on the basis of simple tables will therefore be sufficient. Normally this work can be done by the locally available personnel; moreover the early personnel identification with the project would then result as a desirable consequence. In case of more complicated projects experts may assist the work at site for a short time.

(2) Locally available personnel – and that also at the level of the responsible construction supervisor – does not require a European infrastructure for their daily demands (i.e. the costs for the civil construction remain within a certain scope which does not charge the existing volume of overall investments in an immoderate way).

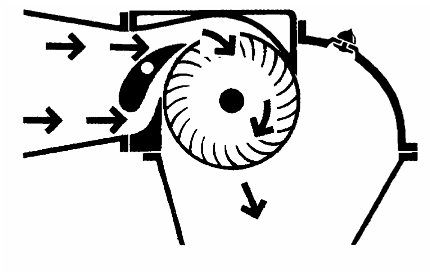
(3) The individual machine components should of course be designed for a simple mounting and a later easy handling. Nevertheless they also should fulfil the demands for robustness and quality as they are required in the respective country.

(4) The overall conception should, with regard to automation and protection, be adequate to the users' comprehension and the size of the power unit.

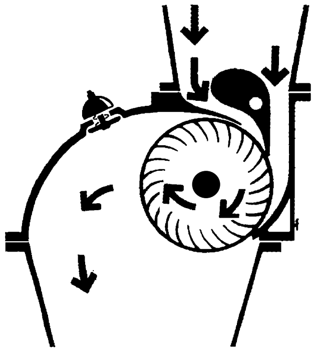
An essential goal should be that simple maintenance work, as it needs to be done during the usual long life of the hydro power unit, can be effected in the own country.

3.2 Ossberger® Turbine

OSSBERGER Turbines are basically individually tailored to the operating conditions to be encountered on a barrage (head/water flow)



Picture 1
Inflow horizontal



Picture 2
Inflow vertical

Flow Pattern in OSSBERGER Cross-Flow Turbines

This flow pattern also has the advantage in practice that leaves, grass and wet snow, which when the water enters are pressed between the rotor vanes, are flushed out again by the emerging water – assisted by centrifugal force – after half a revolution of the rotor. Thus the self-cleaning rotor never becomes clogged.

Principle

The OSSBERGER turbine is a radial and partial admission free stream turbine. From its specific speed it is classified as a slow speed turbine. The guide vanes impart a rectangular cross-section to the water jet. It flows through the blade ring of the cylindrical rotor, first from the outside inward, then after passing through the inside of the rotor from the inside outward.

Where the water supply requires, the OSSBERGER is built as a multi-cell turbine. The normal division in this case is 1:2. The small cell utilizes small and the big cell medium water flows. With this breakdown, any water flow from 1/6 to 1/1 admission is processed with optimum efficiency. This explains why OSSBERGER turbines utilize greatly fluctuating water supplies with particular efficiency.

Efficiency

The mean overall efficiency of OSSBERGER turbines is calculated at 80% for small power outputs over the entire operating range. These efficiencies are normally exceeded. Efficiencies of up to 86% are measured in the case of medium-sized and bigger units.

Figure 4 clearly illustrates the superiority of the OSSBERGER turbine in the partial load range. Small rivers and water courses often have reduced water flows for several months of the year. Whether or not power can be generated during that time depends on the efficiency characteristics of the particular turbine. Turbines with a high peak efficiency, but a poor partial load behavior, produce less annual power output in run-of-river power stations with a fluctuating water supply than turbines with a flat efficiency curve.

Guide Vanes

In the subdivided OSSBERGER turbine the admission of feed water is controlled by two balanced profiled guide vanes which divide the water flow, direct it and allow it to enter the rotor smoothly independent of the opening width. Both guide vanes are fitted very precisely into the turbine casing. They keep the amount of leakage so low that in the case of small heads the guide vanes may serve as shut-off devices. Main slide valves between the pressure pipe and the turbine can then be dispensed with. Both guide vanes can be adjusted independently of one another via regulating levers to which the automatic or manual control is connected.

Casing

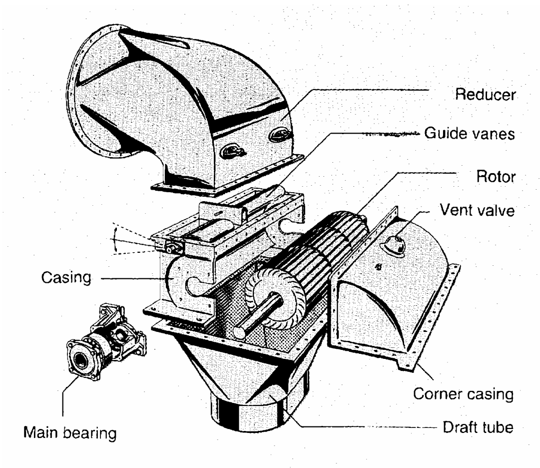
The casing of the OSSBERGER turbine is entirely of steel, exceedingly robust, lighter than a gray cast iron, impact and frost resistant.

Rotor

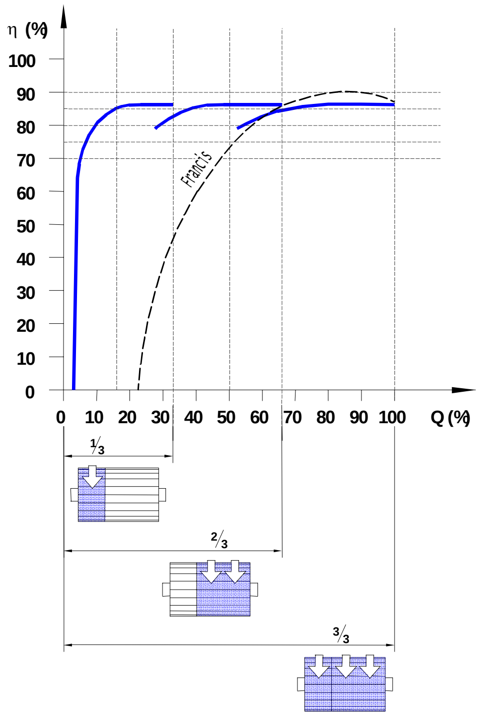
The heart of the turbine is the rotor. It is fitted with blades which are made by a tried and tested process of bright-drawn sectional steel, fitted at both sides into end plates and welded by a special method. The rotor has up to 37 blades depending on the size. The linear curved blades produce only limited axial thrust so that the multi-collar thrust bearings with all their disadvantages are eliminated. In the case of wider rotors the blades have multiple interposed support plates. The rotors are carefully balanced prior to final assembly.

Bearings

The main bearings of OSSBERGER turbines are fitted with standardized spherical roller bearing inserts. Roller bearings have undeniable advantages in water turbines provided that the design of the bearing housing prevents any leakage or condensation occurring. This is the essential feature of the patented bearing construction in OSSBERGER turbines. At the same time the rotor is centered in relation to the turbine casing. Maintenance-free sealing elements complete this superior technical solution. Apart from an annual grease change the bearing requires not any maintenance.



Picture 3 Design of a Two-Cell OSSBERGER Turbine



Picture 4 Efficiency characteristic of an OSSBERGER turbine developed from the 3 efficiency curves of a 1 : 2 division compared with the Francis turbine.

Draft Tube

In its design principle, the OSSBERGER turbine is a free-stream turbine. In the medium to low head range a draft tube is essential however. It serves reconcile the need for high-water safety and loss-free utilization of the full head. On a free-stream turbine with a wide operating range therefore the suction water column must be controllable if the turbine is to be constructed as a draft tube turbine. This is achieved by means of an adjustable air inlet valve which regulates the vacuum in the turbine casing. In this way even heads of as little as 1 m can be fully utilized by OSSBERGER draft tube turbines. Designing the draft tube as a steel bend furthermore considerably reduces the costs of hydraulic engineering at low falls, which is the only thing that makes some developments economically feasible.

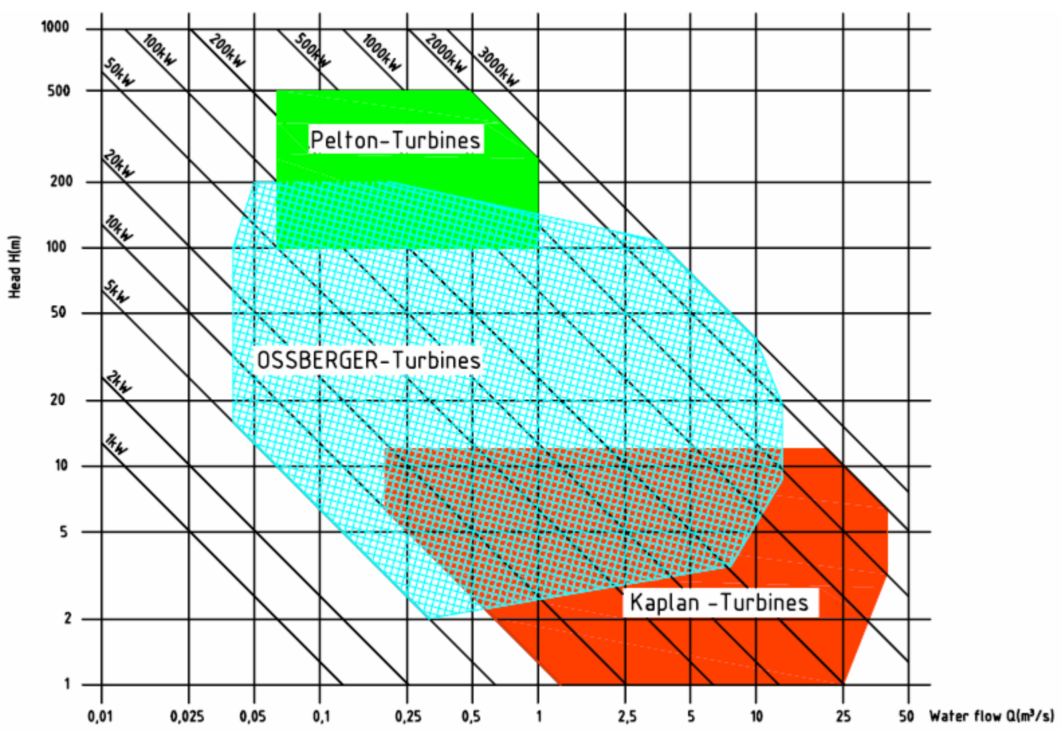
Operating Characteristics

Due to its very design, cavitation does not occur in an OSSBERGER turbine. This obviates the need for installation below the tail water level and all the associated costly structures and operating drawbacks.

The run-away speed of OSSBERGER turbines is 1.8 times the rated speed. This facilitates the use of standard generators.

”Keep it simple” was the watchword when developing the OSSBERGER turbine. It is designed for continuous operation over a period of decades and can be run without any special maintenance equipment. It is frequently installed and commissioned by non-experts – especially in third world countries.

The OSSBERGER Cross-Flow Turbine Compared to the Kaplan Turbine



Picture 5
Range of use

4. Example of Investment:

Different assumptions are required for each example of investment. In concrete cases a calculation of investment costs is therefore necessary for each individual project.

4.1. Investment Costs:

Numerous experiences are available which refer to power stations of heads between 10 and 200 meters and to power outputs of between 200 and 800 kW. A valuation of the said experiences reveals a correlation with the specific investment costs.

With units running at low heads most of the costs are originated by civil work and machinery. For the penstock no costs at all or only little costs need to be expected. With increasing head the expenses for civil construction and machine techniques become smaller, whereas the costs of pressure pipes increase. The expenses due for the electrical-technical equipment conform to the size. This will result in investment costs of between EUR 2500 and EUR 3000/kW.

Moreover the relationship between the imported share and the local costs is of interest. Here the following figures of a plant in Kenya may be referred to as an example:

Head	=	17.3 m
Output	=	361 kW

Cost splitting:

Civil work	53 %
Power train	27 %
Penstock	6 %
Electrical work	14 %

Beyond the environmentally favorable energy production the high share of local costs is advantageous as sources of the own country are utilized. This will help to preserve and create jobs.

4.2 Proceeds

Deciding in favor of investing into a small hydro station no mathematical reflections on finances are essential in most cases. For this reason it will be sufficient to compare the costs with the plant production and the energetic alternatives. With the expenses the costs due for plant and service should be referred to, and with the outcome the proceeds obtained from energy production, taking into account the utilization of the energy.

The costs of the power unit include the investment. Thereto the costs are added for project work and construction management, provision of capital, license fees etc. On the basis of the costs due for the power unit the annual costs will then need to be determined. The same are split up into

- capital costs
- costs of service and maintenance
- taxes, water license fees
- costs due for renovation

The largest share is faced with the capital costs. Two different kinds of redemption of foreign capital are available:

a) by yearly identical rates (annuities), sharing differently into interest and redemption every year, or

b) by yearly identical redemption rates, with interests for the remaining foreign capital demanding smaller amounts every year at the same interest rate.

In most cases the annuity method will be more advantageous for the character of a hydro power station, with high investment costs and a long life expectancy.

The proceeds detail the cost savings for the energetic alternative which is possible in the investigated site. In many cases Diesel units are concerned, with relatively high operating and spare part expenses apart from the investment costs.

If we take, as an example, a power station of 500 kW, utilized at 60 %, the following applies for determining the annual production:

500 kW x 24 hours x 365 days x 60 % = 2 628 000 kWh/year.

Based on the specific investment costs of between 2,500 EUR/kW and 3,000 EUR/kW investment costs of between EUR 1 250 000 and EUR 1 500 000 need to be faced for the said plant. For a rough assessment we are supposing costs of production by a Diesel unit of EUR 0.20 /kWh. So the yearly production of the hydro power station will represent a countervalue of EUR 525 600. No special financial mathematics are required for recognizing the profitableness of an investment of 30 or 40 years lifetime with

investment costs of **EUR 1 500 000**
and
yearly proceeds of **EUR 525 600**.

It will of course be essential to determine a Diesel energy price rate. Experiences made in African countries reveal a range of between EUR 0.15 and almost EUR 1.-- /kWh.

Comparing the low investment cost of a Diesel driven plant with the high investment for Hydro and considering the high running costs of the Diesel and the low running costs of Hydro the following picture shows the time necessary to cover the investment for hydro by the saving on diesel fuel, lubricants and spare part.

For the Diesel power station, prices per machine set generally apply. Differences in the running cost amount mainly occur on how far the location is from the nearest source of supply of diesel oil. For this the comparison is made with two values (a = EUR 0,15/kWH; b =EUR 0,25/kWh). *See attachment 1*

On this, is should be noted, that in this comparison, the procurement costs of the diesel set are only once taken into account, but nor any replacements of diesel engines within the life of a water-turbine plant. Approximate guide-line values for the life of the two prime movers are:

water power plant: 35 years in continuous operation

diesel power plant: 10 to 12 years in intermittent operation
5 to 6 years in continuous operation

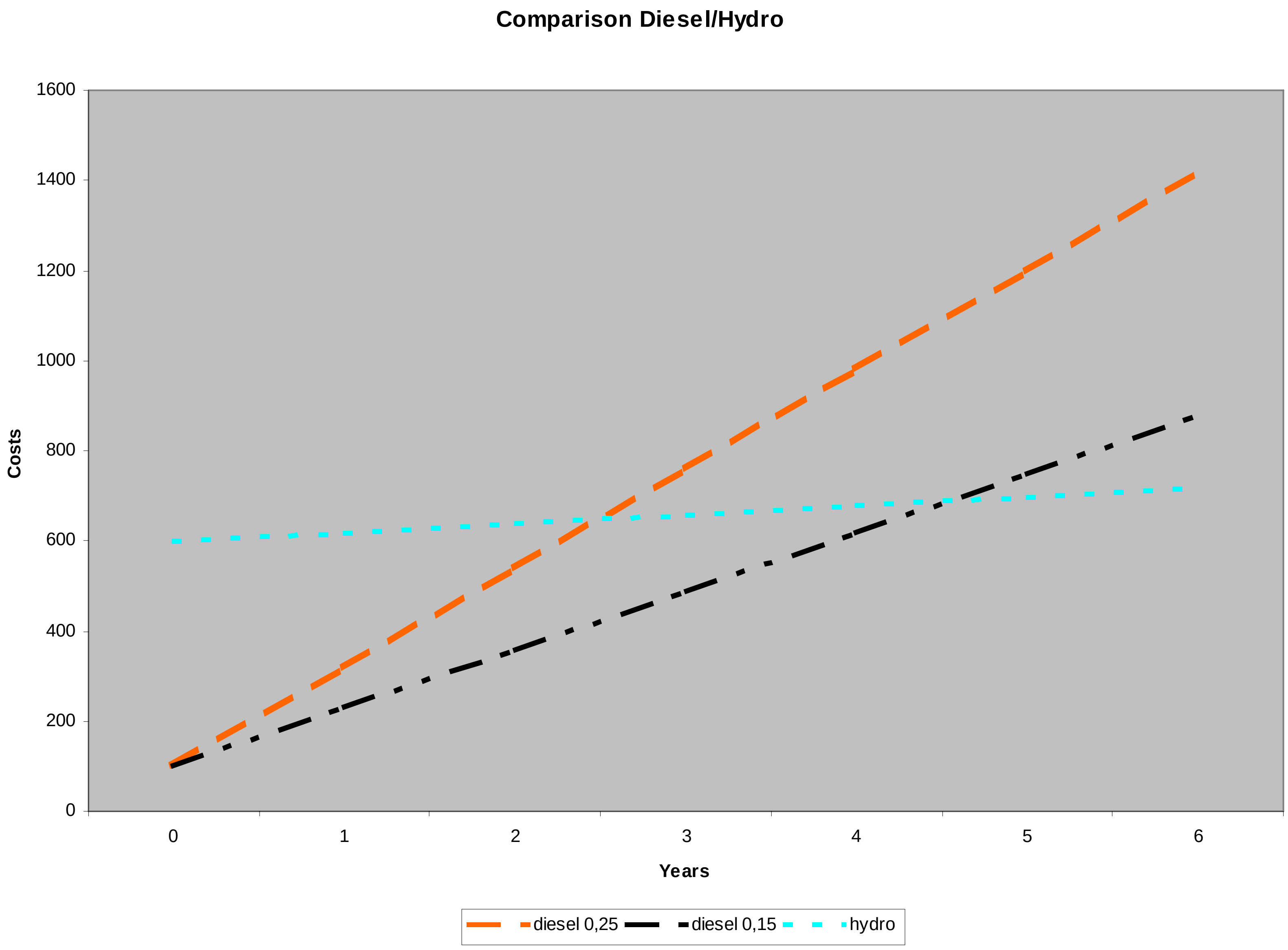
Small decentralized hydro power stations mean a good basis for the future development of any Rural Areas. Apart from ecological aspects the social-ecological as well as the economic effects are essential factors, speaking in favor of this kind of efficient and reliable energy production.

OSSBERGER

Author: Helmut Erdmannsdoerfer MBA Phone: 00 49 91 41 97 70

OSSBERGER GmbH + Co
97181 Weissenburg
Germany

FAX 00 49 91 41 97 720
e-mail: ossberger@ossberger.de
Web: www.ossberger.de


Comparison Diesel/Hydro
Costs
1600
1400
1200
1000
800
600
400
200
0
0
1
2
3
4
5
6
Years
diesel 0,25
diesel 0,15
hydro