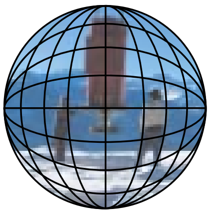


As an energy source, small hydro has few apparent social or environmental consequences, however in order to ensure that the impacts it does have are kept to a minimum there are a series of measures which can be implemented to improve its efficiency and reduce its environmental footprint. By Bernhard Pelikan, Luigi Papetti and Maria Laguna.

Keeping it clean

Environmental integration of small hydropower

Climate change due to CO_2 emissions is the major environmental challenge faced by the International Community, and recent natural disasters and soaring energy prices have helped to focus the world's attention. Renewable energies are the principle solution to climate change. One GWh of electricity produced by small hydropower (SHP) means a reduction of 480 tonnes of emitted carbon dioxide. Various international treaties such as those signed in Rio de Janeiro and Kyoto and along with European Union policies have set clear targets, both for European countries and the rest of the world and show the depth of political intention.

As a form of renewable energy, small hydropower can contribute to the mitigation of climate change in a number of ways:

- ***It is an inexhaustible energy source.*** Unlike fossil fuels, of which there is a finite supply, small hydropower cannot be depleted. Among all renewable energies hydropower is the leading renewable source in the European Union and in the world.

LIFE CYCLE ANALYSIS

At present the only complete way of conducting an overall assessment of the environmental impact of projects of technologies is through life-cycle analyses. These look at the complete impacts of a project 'from cradle-to grave', accounting for construction, materials sourcing, electricity production and materials removal. Looked at from this point of view, run-of-river small hydro schemes have the lowest emissions of harmful substances per unit of energy produced, followed by wind energy.

- ***It does not produce greenhouse gases emissions.*** Hydropower does not involve any combustion, and therefore does not release any oxide to the atmosphere and in particular it does not release carbon dioxide – the principal gas responsible for global warming (Table 1).

- ***It has a high energy-payback ratio.*** For each power generation system, the 'energy payback' is the ratio of energy produced during its normal life span, divided by the energy required to build, maintain and fuel the generation equipment. If a system has a low payback ratio, it means that much energy is required to maintain it and this energy is likely to produce major environmental impacts.

Not only are there global advantages to using hydro power but there are a significant number of local advantages too (regional development and employment). However, as with any technology, there is the potential for some negative local impacts too. The identification of these impacts and the measures required to minimize and compensate for them are the primary focus of this article.

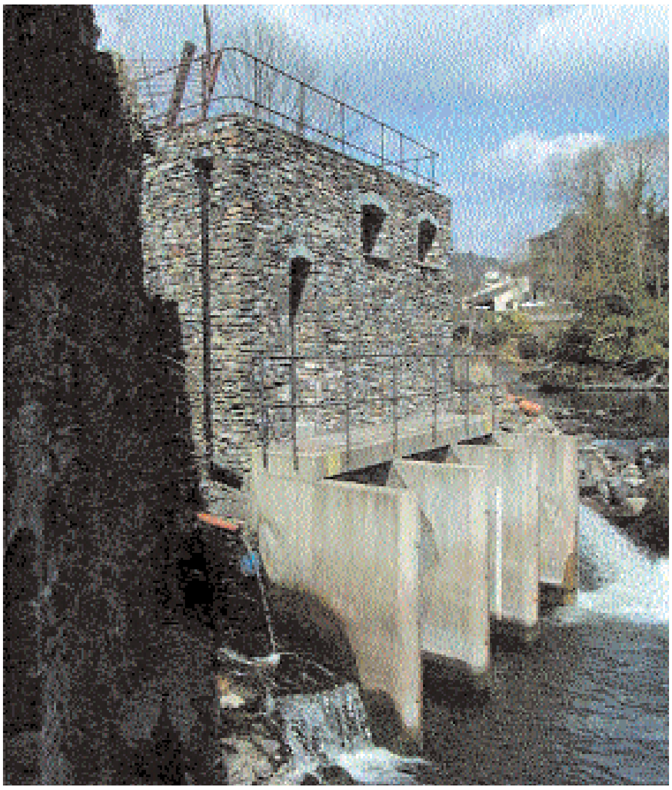
ENVIRONMENTAL IMPACTS

Water from a river has different uses; as potable water, water for agriculture, water for industrial activities, fishing, aquatic sports

TABLE 1. Comparison of emissions from a small hydropower plant of 1000 kW, working 4500 hours/year with other sources of electricity production

	Petroleum (tonnes)	Coal (tonnes)	Natural gas (tonnes)	Hydropower
Carbon dioxide	3000	3750	2250	-
Oxide of nitrogen	3.7	0.6	2.2	-
Sulfur dioxide	4.5	4.5	0.02	-

Installing a small hydro turbine in the mountains of Switzerland MHYLAB



The power house of the 400 kW Backbarrow plant in the UK IT POWER

SHP is one of those activities and, like any human activity, has some impact on the natural environment. However, new technical developments, the current regulatory framework and the willingness of project developers to integrate the environmental concerns of hydropower production have considerably decreased these environmental impacts.

In contrast to large hydropower, which works with big dams and basins that store a large quantity of water, SHP schemes are mainly run-of-river plants with little or no reservoir impoundment. When they are used, little dams create small ponds, which can be favourable for certain ecosystems, as well as improving water retention and benefiting some species of fish. Therefore, SHP is not simply a reduced version of a large hydro plant (LHP). Specific equipment is necessary to meet fundamental requirements with regard to environmental integration, simplicity, high-energy output, maximum reliability, and easy maintenance. Besides the small damming etc., production of electricity by SHP does not produce any significant alteration to the river. The water leaving the turbine has exactly the same quality and quantity than before – indeed some SHP schemes dispense potable water downstream. In addition, SHP schemes assist in the maintenance of river basins by recovering waste that flows in the river stream and monitoring hydrological conditions.

Environmental solutions

In order to insure that the environmental impacts of small hydro power schemes are kept to a minimum, SHP operators are required to conduct environmental impact assessments for any small hydropower project. These assessments allow ecologists to predict the likely impact if any scheme on the local flora and fauna and to define measures which can be taken to mitigate this impact.

There are wide ranges of environmental mitigation techniques which are used by the developers of SHP, some of which are mentioned below.

Reserved flow

All SHP plants diverting water are obliged to ensure a minimum reserved flow downstream of the hydropower plant. All definitions of reserved or minimum flow place emphasis on the protection of the existing ecology of the river.

Fish by-pass systems

Although fish passes were invented some decades ago for the quite different economic reason of fisheries protection, they have become a typical focus of environmental interest. Even more than the system and construction of a hydro power plant, the design of a fish-bypass is a very specific exercise requiring the consideration of a wide range of parameters and restrictions. There are different types of fish passes including fish ladders, vertical slot passes, natural-style fish passes etc.

SHP schemes assist in the maintenance of river basins by recovering waste that flows in the river stream and monitoring hydrological conditions

Trash rack material management

Almost all modern small hydropower plants have a trash rack-cleaning machine, which removes material from the water to avoid it entering the plant waterways and damaging electro-mechanical equipment or reducing hydraulic performance. Each year tonnes of material (mainly plastic bags, bottles, cans, as well as leaves, branches etc.) are removed from the river. In many countries when something, including organic material, is removed from the water, it automatically becomes waste material, which must be properly disposed of with the very high costs of waste disposal. This is undoubtedly a positive impact of small hydropower plants which should be taken into account and support measures implemented to reduce the economic burdens on small hydroelectric plant operators (e.g. by reducing the waste disposal fees or allowing for different treatment between organic and non-organic material).

Creation of adjoining environmental areas

Another policy which can improve the environmental economics of small hydro is the creation of 'environmental areas' which are often developed alongside the generator. These areas are different from site to site and it is hard to generalize on how they are set up. Nevertheless they can contribute to making the small hydropower plant more easily acceptable from the ecological point of view.

MULTIPURPOSE PLANTS

Competition for use of water has always been strong, but in the last few years it has become even more intense. One solution

A natural style fish bypass on the Spielberg river in Austria BOKU

is the multiple use of water resources. This means combining electricity production with other water uses such as irrigation, recreation, and drinking water supply. Such solutions will improve the overall efficiency and very often provide cost sharing opportunities. Multipurpose schemes allow the best compromise among different public interest while reducing the environmental impacts significantly.

Drinking water supply systems

In recent decades many small hydropower plants have been constructed in drinking water systems, especially in mountain areas, where instead of pressure reducing devices small turbines have been installed to exploit head which would otherwise be dissipated. In this case an important multipurpose use of water has been achieved and it is worth taking into due consideration.

Irrigation channels

A lot of small hydropower plants have been installed in irrigation networks or channels, especially in plains where dozens of low head plants exploit the water resource both for irrigation and energy production purposes, supplying energy to the grid or to match electricity demand directly for irrigation (e.g. pumping stations).

Recreation purposes

In some plants the water level in a reservoir or lake has to be kept higher than a certain minimum level to allow angling or other recreation activities. This means that only part of the water volume available can be stored for hydropower purposes.

Flood protection

In many small hydropower plants the river banks near to the diversion works must be rearranged and raised above their normal level. Such action results in an increase of the water level and consequently of the flow rate which the river can convey during floods. Another way to achieve flood protection is the use of the basin to store part of the water volume during floods, although the available volume of storage in small hydropower plants is usually very small compared to the demands of flood protection.

Waste water treatment plant

There are at least two places within a wastewater treatment facility to insert a hydropower installation – above the plant

[redacted]

Noise reduction systems installed on a turbine STUDIO FROSIO

and below the plant. In alpine regions for example there is sometimes a central treatment plant down in the valley where the wastewater is collected from smaller villages high up in the mountains. The head height in such cases is reasonable. Pre-treatment (e.g. trash rack) before entering the pressure pipe is necessary. In cases of larger treatment plants the head available downstream between the treatment and the river may be used. No additional cleaning procedures are necessary.

NOISE AND VIBRATIONS

Small hydro plants are not known for being noisy, nevertheless an SHP may be the source of some noise emission and consequently this must be discussed. The sources of noise from a small hydroelectric plant may be numerous – trash rack cleaner, trash conveyor, generator, gearbox, turbine, transformer – but mainly noise comes from the hydroelectric unit and, when used, from the speed increasers. Nowadays noise inside the powerhouse can be reduced, if necessary, to levels in the order of 70 dB, which is almost imperceptible from outside.

For new plants, integrated and careful design of the whole system, including the hydropower unit, building and ancillaries can allow excellent levels of noise reduction. However there are still some components that are by their nature noisy and in these cases there are several steps which can be taken to dampen them down. These include wrapping sound insulating blankets over the turbine, using water cooling on the turbine instead of air cooling, careful design of ancillary components and acoustic insulation of the building. Taken together these steps can make the plant virtually imperceptible.

FISH-FRIENDLY TURBINES

The installation of turbines in a river system may in certain circumstances endanger fish. Research work, carried out at large hydropower stations has shown that fish can and do get into the turbine, especially in periods of intensive fish movement along the river. For a variety of reasons (mechanical, speed, pressure variation) not all these fish survive passing through the turbine. Deterrent equipment (lights, certain noises, etc) may cause some reduction but they still do not completely prevent fish from entering the turbine. In the case of SHP however, as opposed to large hydro, there has been almost no serious investigation of this topic. While trash racks with a narrow bar-distance of some 2 cm may stop most fish from entering the turbine further efforts must be made to reduce the danger to fish by using alternative turbine designs.

To help minimize fish injury, turbine manufacturers have been carrying out studies based on computational fluid dynamics (CFD), with good results. Small hydropower plants also can take advantage of this research with methods developed for minimizing impact on fish from conventional turbines (Francis and Kaplan turbines). Meanwhile new concepts of turbines and re-invention of old concepts (hydrodynamic screws, water wheels) are typical of micro and mini hydro plants, allowing better integration into and preservation of the river life.

One such old-technology-made-new is the archimedic screw. Although originally designed to pump water, the archimedic screw can be inverted and has been used for some time as a niche technology in SHP markets. These screw systems are sometimes significantly cheaper than conventional turbines and are reliable and robust in operation. In general they do not need a fine trash rack and are comparatively fish friendly.

CASE STUDIES IN THE ENVIRONMENTAL INTEGRATION OF SHP IN THE EU

The use of appropriate technologies, measures or methodologies has minimized potential environmental impact. Some examples are described below.

Backbarrow UK

Commissioned in 2001, the 400 kW Backbarrow plant is located 3 km downstream of Lake Windermere in the Lake District National Park. The scheme utilizes water from the River Leven and is in a scenic and therefore sensitive location. The river also provides considerable revenue generation through salmon fishing. The site upon which the scheme is built has historically been used to harness hydropower. Due to the location, fisheries issues and historical value, a great deal of consideration was given to the environmental design of the new scheme. Through consultation with parties mentioned above and the Environment Agency, specific requirements regarding visual impact and fisheries protection were incorporated into the design.

ENVIRONMENTAL MEASURES

In order to help the powerhouse blend in to the background, it is located below river-bank level and 'dressed in local materials', making it invisible from upstream and similar to existing structures. Just upstream from the turbine intakes, three Trashclean© racks were installed, each with its own cleaning rake. This was necessary because the site has a history of high levels of weeds and other debirs.

To help protect fish, a Bio-Acoustic Fish Fence (BAFF) was built into the existing forebay to guide fish into the bypass, helping to ensure that they avoided the turbine while an eel guide and escape sluice were also constructed. In addition, the turbine draft tubes were positioned so that the exit flow would provide an attraction flow for upstream migrating fish, drawing them towards the fish-pass. These draft tube exits are shielded by Electroscreens©, an innovative electrical barrier which deters migrating fish from attempting to swim up the draft tubes.

Kavarskas, Lithuania

The Kavarskas site is located on the River Sventoji 69 km upstream its mouth (average flow is 31.4 m^3/s), near the same name small settlement. In 1962 a 4.1 metre high dam had been built, which had created a 0.8 km^2 resevoir. The plant was commissioned in 2002 and has a total capacity of 1 MW.

ENVIRONMENTAL MEASURES

The river Sventoji downstream from the Kavarskas dam is famous for its migrating fish and following the construction of the dam it was declared a protected area. Salmon, trout, vimba and other valuable species are commonly found in the stream. In 2001 the private SHP development company Achema Hidrostotys was given permission to construct a small hydropower plant at the existing dam, providing the fisheries issues was taken into consideration. For that a fishpass was needed. The run-off-river scheme has been designed by local design company Kaunas Hydroprojektas, with the physical modelling of the fish ladder constructed in the laboratory by the staff of the Water and Land Management faculty at the Lithuanian University of Agriculture. The fish ladder is a concrete structure, pool-type with vertical slots, and was built at a total cost of 300,000 – roughly 10% of the total cost of the project. A year later, after more than 40 years, the fishermen have reported the reappearance of migrating fish upstream of the Kavarskas SHP, a fining which has been confirmed by ecologists monitoring the project.

> Noise inside the powerhouse can be reduced to levels in the order of 70 dB, which is almost imperceptible from outside

Troistorrents, Switzerland

This 75 kW system is built into the drinking water system of the Troistorrents commune and harnesses the high differential in water level between the catchment chamber and the surge tank, were it functions as a pressure regulator device. As the generator was part of the drinking water system it had to meet rigorous health and safety standards.

ENVIRONMENTAL MEASURES

As the plant was constructed within the drinking water network it removed the necessity for certain types of infrastructure such as trash racks or a fish friendly design. However as the plant was located in a semi-agricultural area special efforts were taken to minimize its effect on the landscape. Consequently the outside of the turbine house looks just the same as a traditional Swiss chalet. Because there are houses nearby the turbine is highly efficient and quiet-running and so can only be heard with the door open.

In terms of power efficiency the plant is highly environmental as it provides pressure to the water supply network and extracts energy that would otherwise be wasted in a pressure reducer. Altogether the installation saves the emission of an estimated 110 tonnes of CO_2 per year.

The turbine in the Troistorrents drinking water system MHYLAB

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