Position Paper

THE POTENTIAL OF SMALL HYDRO FOR RURAL ELECTRIFICATION

FOCUS : Latin America






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Alliance for Rural Electrification

Shining a Light for Progress

1. Executive summary

In a time when the world is looking for qualitative solutions for substantially increasing energy access, particularly in developing countries, it is crucial for the Alliance for Rural Electrification (ARE) and its partners to underline the role small hydropower (SHP) can play.

This paper focuses on the innovative aspects of SHP to make it a competitive technology for rural development. It provides technical information, explains the considerable benefits of SHP as well as its role in reducing energy poverty and creating business development. It also addresses the current challenges, opportunities and public sector support for SHP in Latin America.

Overall, the paper demonstrates that SHP is an appropriate and clean as well as reliable and highly efficient solution for making rural electrification and thus energy access happen.

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2. Recommendations

In order to create an enabling environment for SHP in Latin America, we recommend that energy-sector decision makers, such as ministries of energy, power regulators, rural electrification/energy or renewable energy agencies and public utilities, take the following steps:

- Amend policies and legislation on electricity tariffs, subsidies and concessions in such a way that the development of SHP is favoured or at least not impeded;
- Further develop preferential policies and measures that encourage SHP development, e.g. tax reductions, soft loans and grants as well as encouraging private firms to invest in SHP schemes;
- Establish policy targets for SHP and determine target areas in order to increase the visibility of the sector and raise awareness on its importance. An action plan should be established that sets out a roadmap facilitating and monitoring the process;
- Further develop specific support funding/finance schemes for SHP and/or technical assistance to the banking and microfinance sectors;
- Invest in capacity building so that local communities better understand SHP, taking best practices into account;
- Expand the availability of data on potential sites and meteorology and enhance the visibility of reliable local partners by certifying them and establishing a database;
- Where appropriate, improve regulations regarding the protection of supply areas and private property and develop fast and inexpensive procedures such as for importing equipment.

3. Definition

This paper focuses on SHP. In the absence of a globally agreed definition of 'small' hydro, the upper limit is usually taken as 10 MW, although this can be higher in some parts of the world.

Smaller schemes are further generally divided into mini hydro (typically less than 1 MW), micro hydro (less than 100 kW) and pico hydro (less than 5 kW). In Latin America, the Latin American Energy Organization (OLADE) has defined small hydro plants as 500 to 5000 kW, mini hydro plants as 50 to 500 kW, and micro hydro plants as < 50 kW.

4. General overview of SHP technology

Most SHP plants are run of river schemes (see below) and store little or no water. In principle, micro and pico hydro technologies are used in developing countries to provide electricity to isolated communities where the electricity grid is not available, whereas mini hydro tends to be grid connected. Moreover, regarding micro and pico hydro, the scheme design can be considered on a per household basis or at village level often involving local materials and labour, whereas mini hydro schemes require traditional engineering approaches. Furthermore, mini hydro schemes will often require an access road to be built for construction materials and heavy electro-mechanical equipment to be delivered to the site, whereas most micro-hydro schemes can be built with purely manual labour in more remote locations[1].

A crucial difference is in terms of load control. Since the electricity from micro and pico hydro schemes is supplied directly to households, there is no large grid to control the frequency and voltage of the electricity supply, hence a local load controller is necessary. For pico hydro, the turbine/generator set can be bought as a modular, off-the-shelf unit, unlike the equipment for larger schemes (micro hydro and upwards) where the turbine has to be specifically designed for a particular site[2].

4.1. Typical 'run of river' scheme

SHP plants are usually 'run of river' schemes. The power flow in such an SHP system can be depicted as follows[3]:

4.2. Technical aspects of SHP plants

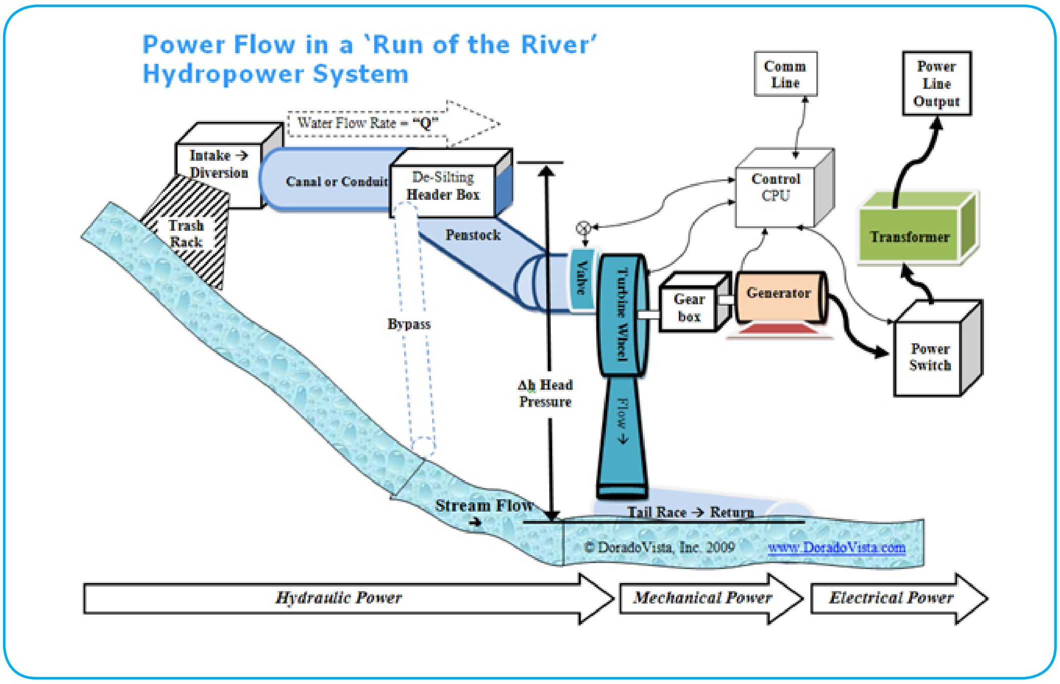
Generally speaking, hydropower systems use the energy in the water to produce electricity. Hydraulic power is in effect captured from a mass of water moving at a flow rate. The vertical fall of the water ("head") is a critical parameter in the design of hydropower systems[4].

The SHP system in itself is composed of a turbine and a generator. Hydro turbines cover a huge range of capacity from 0.2 kW up to 800 kW and can therefore provide an adequate solution to every local situation, provided that a suitable water flow is available.

The most important types of hydro turbines covering almost every situation are the "Pelton", "Banki" (both also called "cross-flow"), "Francis" and "Kaplan" turbines. The cross-flow turbine is adapted to high heads whereas the Kaplan is more used for low head rivers. Pelton, Banki and Francis turbines can be installed with a horizontal axis, which makes maintenance easier whereas the Kaplan units normally have a vertical axis.

In the case of the Pelton and Banki turbines, called impulse turbines, the water pressure is converted into kinetic energy (in the form of a high-speed jet) before entering the runner and generating electricity. In contrast, in the Francis and Kaplan turbines, called reaction turbines, the water pressure directly applies on the face of the runner blades to produce energy. They are more complex to build and install than the impulse ones, but have a higher efficiency.

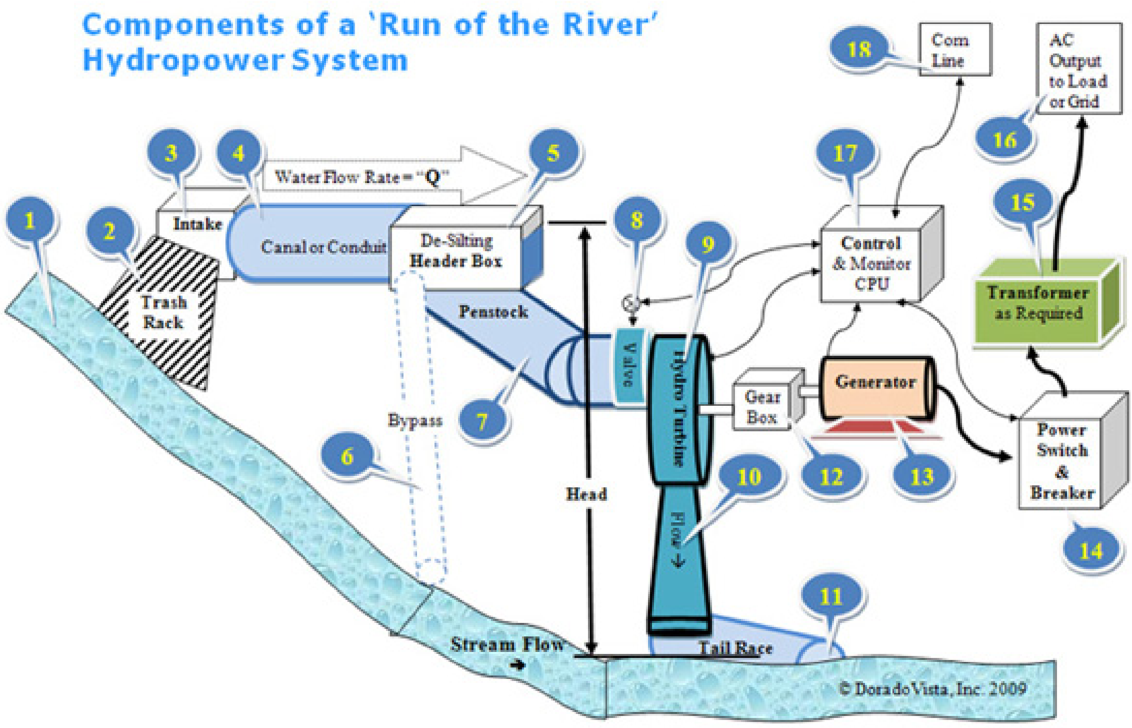
There are three types of generators that can be combined with the turbine: (i) the generators with permanent



1 ESHA/IT POWER, "Small Hydropower for Developing Countries", p. 4.
2 *Ibidem*.
3 "Power flow in a 'run of the river' hydropower system", available on http://smallhydro.com/small-micro-hydro-info/ .
4 EPU-NTUA (2008), "Scientific Reference System on New Energy Technologies, Energy End-use Efficiency and energy RTD - Executive Summary on Small Hydro", p. 2.

magnets for small units (up to a few kW), (ii) the asynchronous for grid connected plants, and (iii) the synchronous generators (with load regulation by means of ballast loads) for bigger units.

The following figure represents the basic components of a small or micro hydropower system[5].



1. Stream flowing past intake and outlet points with sufficient flow and head to be worth hydroelectric development.
2. Trash rack or intake screen (Coanda wedge wire or bars with cleaner).
3. Intake water diversion structure, diversion gate valve and settling basin.
4. Diversion channel, canal, ditch or pipe at atmospheric pressure. Water flows at rate 'Q' from here to tailwater.
5. De-silting header box for flow regulation into penstock where pressure builds and any water hammer can vent.
6. Bypass conduit to allow system to clean out silt buildup and vent any excess flow.
7. Penstock, the main pressure building conduit. As high head pressure can be dangerous, one must be careful if the head is large, 130 psi or greater.
8. Inlet regulation valve for turbine. This is the throttle for controlling power and system shutdown. This valve regulates the power into the turbine to balance the output from the generator.
9. Hydro Turbine or Wheel depending on type of system chosen (impulse or reaction).
10. Draft tube. It is used in the reaction turbine or as a simple atmospheric tailrace chamber.
11. Tailrace. This is the channel for slowing and redirecting water back into the stream.
12. Gear box or belt drive to provide the most efficient range of turbine operation and to maintain generator output at correct frequency.
13. Generator.
14. Power switch and breaker. It is a safety device to disconnect power.
15. Transformer. AC conversion of generator output to transmission line or use of the voltage.
16. AC output to load or grid.
17. Control and monitor CPU. This unit balances the power of the flow into the turbine with the power of the generator (load) and has a safety monitor as well as override controls.
18. Communication line. Connection to an outside computer link which allows for remote monitoring and controlling of complete system parameters[6].

[5] "Components of a 'run of the river' hydropower system", available on http://smallhydro.com/small-micro-hydro-info/components-of-a-small-hydropower-system/ .

[6] See on "unattended" hydro plants: HNAC TECHNOLOGY, "Characteristic & Proposal "Unattended" Medium & Small Hydropower station", available on http://www.renenergyobservatory.org/uploads/media/wangXiaobingR2.pdf .

5. Site location and installation

Unlike conventional hydroelectric power plants, SHP plants (or run-of-river power plants) have little to no water storage capacity, so are best located on rivers with a consistent and steady flow. Areas with the best resources are those which offer an elevation drop, high annual precipitation rates, and catchment areas from which water will drain into the rivers.

There are three types of SHP plants: using weir, diversion canal and kinetic power. The gravitational energy of the water due to the elevation drop (i.e. height difference, or head) is used by weir and diversion type plants to generate power. The kinetic energy of fast rivers can be harnessed by kinetic energy devices.

Hilly or mountainous regions are most suitable to weir and diversion type plants, since the energy production increases with the elevation drop of water whereas for kinetic turbines, the best location is on a plain, but rivers must have the following characteristics: a year-round continuous flow, a velocitiy greater than 1 m/s, suitable depth, a solid and stable riverbed and sediment-free water.

Installations are usually situated at strategic points where the land provides a natural flow restriction, resulting in locally high velocities. The strongest currents in a river are located in the centre and close to the surface, where they are not inhibited by friction with the river banks and bed. As a river flows around a bend it accelerates around the outside and slows on the inside of the bend.

Beside the choice of the scheme and the system, the plant's layout and surroundings are main issues with hydropower as this technology interacts with its environment more than any other. SHP requires a deep knowledge of the site with respect to geomorphology and hydrology in order to reach reliable predictions of the availability and time distribution of the flow rates.

This hydrological work should not be limited to the minimum value and the range of available flows, but must also include the maximum flood of the river, in order to avoid any damage to the diversion works and to third parties' properties. Whereas the plant head can be precisely measured, the flow rates evaluation must be done by proven specialists, who employ statistical methods, direct measurements at gauging stations, etc.

Moreover, environmental engineering should also be involved to study elements such as landslides, instability or critical passage zones as well as to access other environmental factors (e.g. fish migrations).

6. Cost calculations

SHP is often presented as the cheapest technology for rural electrification over the lifetime of the system. However, an SHP plant can require substantial initial capital investments even though its operating costs are very low. It is generally considered that location and site preparation determine around 75% of project costs against only 25% for the equipment.

Therefore, a simplified feasibility study of the project should be developed in order to gather accurate estimations of hydro-technical parameters at the site of the power station and to give a rough balance of costs and expected benefits. A small hydro plant will include turbine, generator, batteries, pipe, the inverter and other mechanical and electrical components to which civil works must be added, including a weir, powerhouse, headrace, tailrace, installation of penstock and valves.

Although the preparation of such a plant requires technical expertise, the installation of the plant in itself is relatively straightforward and costs can be reduced by using many local materials and skills.

When creating a financial plan for SHP, several elements should be taken into consideration: (i) developers should be aware that the preparation of project documentation and feasibility studies can represent a substantial percentage of the total costs, (ii) there are the possibly considerable costs of the hydrotechnical infrastructure and (iii) the life span of an SHP scheme is often longer than the time needed to amortise the investment. Here is an example of the investment cost breakdown after evaluation work:

Element of investment	Participation up to (%)
Hydrotechnical construction	60
Turbines	25
Building	5
Electrical equipment	10
Cost of exploitation	0,5

7. Why SHP can greatly enhance rural electrification

As a mature and reliable technology, SHP has considerable competitive advantages and huge potential. Therefore, SHP technology proves to be a very interesting clean solution to enhance rural electrification by increasing the supply of affordable and sustainable electricity.

It is a local energy source that makes use of small rivers. Even though the amount of generated electricity is site specific, it is important to note that there is an enormous potential, particularly in developing countries. As a local energy source, it is also very well suited to enhance rural electrification and the development of local technology and skills. The local community can often run the scheme, do minor repairs and change spare parts, if a proper technology transfer and capacity building is provided.

SHP is also a highly competitive and economical technology[7]. Even though an SHP plant can require substantial initial capital expenditures (capex), it has very low operating costs (opex). It should be underlined that, when compared to a diesel generator set, an SHP plant can experience higher upfront investment costs, but this is by and large offset by the absence of fuel costs.

In addition, SHP plants are reputed for their longevity (up to 100 years) and their high efficiency (from 70% to 90%). They therefore offer an attractive energy pay-back ratio even for developing countries.

Furthermore, unlike other technologies that rely on variable sources, such as local wind speed and solar radiation, a stream's flow is relatively consistent, adding to the predictability and reliability of the outputs. Micro-hydroelectric systems, in particular, have been characterised as the most predictable of all the renewable energy electrical systems[8]. SHP thus greatly enhances the security of supply and is able to fill the gap of increasing energy demand.

SHP is equally an environmentally friendly and sustainable solution. In contrast with large hydro schemes, it usually does not require huge water reservoirs. Consequently, it has a limited or inexistent impact on hydrological regimes, sediment transport, water quality, biological diversity, land-use change, the resettlement of people or effects on downstream water users. Importantly, it does not produce heat or greenhouse gas emissions.

Also, SHP projects can be developed under the Kyoto Protocol's clean development mechanism (CDM). This mechanism allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO^2. These CERs can be traded and sold, and used by industrialised countries to a meet a part of their emission reduction targets under the Kyoto Protocol[9].

Finally, SHP schemes can be designed to recover energy from existing infrastructures. Such a multi-purpose scheme implies the integration of the power plant in the existing infrastructure while guaranteeing its primary function[10]. For example, an SHP plant could be integrated in a drinking water or irrigation network, before and after a wastewater treatment plant, in a desalination plant, etc.

These multi-purpose schemes do not only greatly expand the potential of SHP, but they also contribute to finding solutions for water policy issues such as the sustainable management of the resource in sectors like agriculture, wastewater treatment or drinking water supply.

[7] See the section on cost.
[8] P. CUNNINGHAM and I. WOOFENDEN (2007), "Microhydro – Electric Systems Simplified", Journal Home Power, pp. 40 – 45.
[9] See for more information on the CDM: http://cdm.unfccc.int/about/index.html .
[10] See SHAPES and SIXTH FRAMEWORK PROGRAMME, "Energy Recovery in Existing Infrastructures with Small Hydropower Plants – Multipurpose schemes – Overview and examples", 53 p.

8. Role of SHP in reducing energy poverty and creating business development

For the reasons mentioned above, **SHP is a very convincing solution to develop in rural areas where 84% of the world's un-electrified population (approximately 1,2 billion people in total) is concentrated**[11].

According to the Energy Access Practitioner Network, 60% of the additional generation that will need to be installed by 2030 to achieve universal electricity access will be off-grid[12]. The objective of ensuring universal access to modern energy services by 2030 has been formulated in the framework of the UN's Sustainable Energy for All initiative, and reaching it will have a decisive influence on the achievement of the Millenium Development Goals[13]. **SHP is an excellent option to promote productive uses, economic growth and development for small remote communities in developing countries, because**[14]:

- Hydro is usually the **least cost** of all electrification options for isolated communities, where hydro resources exist;
- Hydro energy is a **mature technology**, widely proven and now manufactured in a number of developing countries;
- Hydro energy resources are **highly predictable**, and normally generate energy 24 hours a day, so they can safely be used to provide a range of services, such as health and education centers, drinking water, communication etc.;
- Hydro is an appropriate energy option for intensive energy consumption, because the **marginal costs for electricity generation are negligible**, and it has proven to be effective in a number of applications such as chicken farms, wood processing, agro processing, milk chilling, small mining, and other productive uses and small businesses;
- It is **adaptable to the local skills and capabilities** for implementation, operation and maintenance;
- Hydro is a **clean energy source**, which can be harnessed with minimum alteration of the environment and no greenhouse gas emissions.

From a business perspective, it is vital to note that the **SHP markets have enormous potential, certainly in developing and emerging countries.** Whereas the global installed SHP capacity (up to 10 MW) is estimated to be 75 GW in 2011/2012, the SHP **potential globally is approximated at almost 173 GW**[15].

In this context, **Latin America and the Caribbean appear to be particularly interesting** regions for implementing SHP schemes, as appears from the table below[16].

[11] IEA, World Energy Outlook 2013.

[12] ENERGY ACCESS PRACTITIONER NETWORK (2012), "Towards Achieving Universal Energy Access by 2030", United Nations Foundation.

[13] See for information http://www.se4all.org/our-vision/our-objectives/ and http://www.unfoundation.org/what-we-do/issues/energy-and-climate/clean-energy-development.html .

[14] PRACTICAL ACTION, "Small-scale hydro power", available on http://practicalaction.org/small-scale-hydro-power-2 .

[15] H. LIU, D. MASERA, and L. ESSER, eds. (2013), "World Small Hydropower Development Report 2013", United Nations Industrial Development Organization, International Center on Small Hydro Power, available on www.smallhydroworld.org . The world's electric power consumption in 2011 was 20.329.882 GWh. Data extracted from http://www.worldbank.org/ .

[16] Data extracted from H. LIU, D. MASERA, and L. ESSER, eds. (2013), "World Small Hydropower Development Report 2013", United Nations Industrial Development Organization, International Center on Small Hydro Power, available on www.smallhydroworld.org and from the Energy-Economic Information System (SIEE – OLADE).

Country	Population (million)	Rural population (%)	Electricity access (%)	Electrical capacity (MW)	Electricity generation (GWh/year)	Installed Hydropower capacity (MW)	Hydropower generation (GWh/year)
Argentina	40.41	8	97.2	33 810	128 922	10 045	39 920
Belize	0.344	48	85.0	144	388	53	250
Bolivia	9.92	33	77.5	1 459	6 085	477	3 876
Brazil	190.75	13	99.0	117 134	532 872	82 458	403 250
Chile	17.11	11	98.5	17 530	62 429	5 991	23 871
Colombia	46.29	25	93.6	14 424	64 230	9 718	38 714
Costa Rica	4.658	36	99.3	3 108	9 704	1 682	7 262
Cuba	11.252	25.0	97.0	6 240	17 387	64.0	>80
Dominica	0.073	33.0	95.0	27	89	6.4	32
Dominican Rep.	9.927	31.0	93.0	3 394	14 580	540.0	1 383
Ecuador	14. 46	33	93.1	5 090	20 544	2 242	9 170
El Salvador	6.000	36	86.4	1 312	5 763	472	2 079
French Guiana	0.23	24	..	284	838	129	..
Grenada	0.112	61.0	96.7	49	224	0	0
Guadeloupe	0.503	1.8	..	..	..	9.5	21
Guatemala	14.388	51	80.5	1 477	8 147	891	3 752
Haiti	9.993	48.0	38.5	267	687	61.0	300
Honduras	7.600	48	70.3	1 722	7 127	531	3 081
Jamaica	2.889	48.0	92.0	872	5 001	22.0	152
Mexico	113.423	23	97.7	61 155	291 544	11 542	35 796
Nicaragua	5.788	43	72.1	895	3 781	105	326
Panama	3.516	25	88.1	2 391	7 858	1 351	3 971
Peru	29.07	23	85.7	8 556	12 975	3 453	20 038
Puerto Rico	3.690	1.0	100.0	5 840	22 558	100.0	133
St. Lucia	0.175	72.0	98.0	76	341	0	0
St. Vincent & the Grenadines	0.121	51.0	..	49	139	5.6	17
Uruguay	3.35	8	98.3	2 683	9 890	1 538	8 050

9. Challenges, opportunities and public sector support

SHP faces several challenges in Latin America, most of which can be relatively easily resolved. In particular, a lack of appropriate and stable regulations related to tariffs, subsidies and concessions, which presently do not help or encourage its development, can often be observed.

Moreover, the financing of SHP projects is often difficult, as governments often prefer large projects for reputational reasons, rural populations have limited financial resources and financial institutions should focus more on tailoring financial products to the specificities of SHP projects. In this context, there should be more preferential policies and measures that encourage SHP development, e.g. tax reductions, soft loans and grants as well as encouraging private firms to invest in SHP schemes.

Other identified issues are insufficient capacity building and determination of target areas, difficulties in finding reliable local partners, lack of data on potential sites and meteorology, inadequate rules to protect supply areas and private property as well as the need for fast and inexpensive procedures such as for importing equipment.

However, in order to promote the increased use of SHP, there are financial institutions such as the World Bank and the Inter-American Development Bank, which give loans for rural electrification projects that can be used for SHP. In addition, many developing countries are restructuring their power sector and frequently encourage self-generation by end-users using smaller-scale technologies.

Crucially, Latin American governments have developed a significant number of incentives for small hydro schemes (see table below). Such incentives include preferential prices for transport and energy production, priorities in the dispatch of the generated energy, income tax exemptions in various percentages, as well as to provide readiness to energy trading, to foreign capital inflows and project financing[17].

[17] OLADE, "The Small Hydro Plants in Latin America and the Caribbean – Small Hydro Energy: Local Solutions to Climate Change and Sustainable Development", presentation during the 1st Latin American Hydro Power and Systems Meeting

Country	Acts/ Incentive programmes
Argentina	• National Act on the promotion of renewable energy for electricity production (Act 26190/06). • Electricity Supply Program for the Rural Dispersed Population in Argentina. It establishes provincial energy programmes for rural electrification, mainly using photovoltaic, wind, micro hydro turbines and diesel generators. • The most recent policy on renewable energy was established in early 2010, when Argentina had implemented incentives in the tariffs for granting power purchase agreements (PPA) for renewable energy. It includes mini hydro projects.
Bolivia	• A Rural Electrification Decree was approved in 2005 (Supreme Decree No. 28 of 567). It aims to increase rural electrification through renewable energy development and a change in the energy mix. • There is a hydropower program dedicated to developing technologies to use water resources. Its goal is to get technology packages developed in different research projects, ready to be transferred to the end users, preferably the rural population.
Brazil	• The current Act 10438/02 led to the Incentive Program for Alternative Electricity Generation (PROINFA-Programma Fonres Incentive Alternatives), which aims to encourage the involvement of mini hydro in the national grid. • Free energy trading allowing producers to sell energy directly to consumers through the network at a 50% discount rate to use the network (Act No. 9648). • Exemption of the financial compensation for the use of resources (Act No. 7990-No. 9427).
Chile	• Renewable Energy Electricity Act and Electricity Short Acts I and II, which proclaim the following: (i) the free transit of the energy through the network for plants with installed capacity under 9 MW and the proportionate share of transit for plants between 9 MW and 20 MW as well as (ii) the electricity distribution companies must purchase the energy generated from all kinds of small plants and the price is set periodically by the Ministry of Energy.
Colombia	• Act 697 makes available the incentives for R&D in the field of mini hydro plants. • Incentives have been implemented as research grants, tax exemptions and fee waivers by reliability for SHP (<20 MW).
Ecuador	• Preferential costs depending on the energy source of the plant and the preferential entry to the network. Regulation 004/011 - CONELEC.
Peru	• Act of investment promotion for electricity generation (Act No. 1002). • Priority dispatch of transmission system operators.
Uruguay	• Regulation 354/009 promotes the electricity generation from non-traditional renewable sources and grants a waiver of a significant percentage of income tax for generators. • Decree 455/007 provides tax benefits that may be granted (deduction of taxes in accordance with the amount of investment, tax exemptions, VAT refund).
Honduras	• There is a revolving fund to help finance SHP plants with an installed capacity of up to 5 MW.
El Salvador	• Tax exemption of 10 years for projects under 10 MW. • Plans to develop renewable energy have been identified in a Master Plan (March 2012).
Dominican Republic	• In 2009, a four year rural electrification programme was implemented, initiated by the Government, where the objectives were to promote energy access across the country and the use of renewable energy sources in marginalised rural communities. This initiative operates in 55 rural communities. It is planned to install a total of 31 micro hydro schemes and a wind turbine that will generate an average availability of 200 Wh per household. • Act No. 57-07 on Incentives for Development of Renewable Energy Sources and its Special Regimes. Where it stands: exemption from income tax, tax relief for external financing, bond emissions reduction for projects through mini hydropower plants up to 5 MW.
Nicaragua	• Act 476 for the Promotion of the Hydropower Subsector states that hydropower schemes under 1 MW do not need a water concession, whereas systems with capacities from 1 MW to 5 MW must be granted one for 15 years. A simplified procedure is applied to obtain a water concession from MIFIC. • Act 217 General Act of Environmental Protection and Natural Resources states that projects with a capacity below 5 MW do not require an environmental impact assessment. • The income tax does not apply for a period of up to seven years (Act 532).
Cuba	• The 2006 "Energy Revolution" programmes addressed energy savings and efficiency, a higher availability of power services (implementation of distributed generation and rehabilitation of the network) and the use of renewable energy.
Jamaica	• The objective of the government is that 15% of total generation capacity of the network work should be provided from renewable energy resources by the end of 2015. Furthermore, a bonus of up to 15% above the utility avoided costs will be allowed to purchase electricity generated from renewable sources.
Costa Rica	• There is an ambitious National Development Plan that aims to achieve carbon neutrality by 2021. It also aims to reach an electrification rate of 100 % using decentralised systems.

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Case study 1
Salvajinas
Smart Hydro Power
COLOMBIA

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Service: Test Site for combined hydro-photovoltaic off-grid system
System: off grid with option to integrate diesel genset as emergency or connect to grid and build UPS
Generation: 1.6 kW peak PV and 5 kW hybrid

Smart Hydro Power develops, designs, fabricates and commercializes pico hydrokinetic systems.

The Challenge
Up to now off grid renewable systems are mainly built upon photovoltaic systems with 1500 to 2500 hours of generation a year. There is no base load solution if not diesel generator huge battery banks which both drive costs.

The Solution
Pico hydropower is a base load solution. Hydrokinetic systems can even be installed where there is no natural head and no infrastructure can be or shall be built up. The reference case in Salvajinas has the purpose to show how the combination of photovoltaic (PV) and pico hydrokinetic can source with 100% availability an off grid installation.

The turbine is installed in the outflow of Salvajinas hydro power plant which operates flexible in the market. This simulates different flow rates in the outflow and allows showing how PV and hydropower can be used as reliable sources even with varying flow rates and limited radiation over the day.

Different AC and DC coupled electrical systems were built up to show how PV and the turbine can feed into the same system minimizing the size and the loading cycles of the battery bank. In one test installation the system was connected to the low voltage grid (between two phases at 110V) to simulate a UPS-design (uninterrupted power supply).

The steering of the system is as easy as a simple PV system steering with the hydrokinetic turbine being steered into a sub-optimal working point whenever batteries are fully loaded and total supply passes total demand.

Different demand profiles were simulated using the workshop of the hydropower plant as point of demand. This allowed to vary demand between 250 Watt to 10 kW so also sudden peaks and impact of high reactive current on hydrokinetic system could be tested.

During commissioning phase there were minor problems when the turbine was falling dry during low / no production of the hydropower plant. The problem was solved by enforcing the blades and the base of the turbine. Since then the system has run uninterrupted with 100% availability.

Case study 2

Energy for Poverty Reduction in Rural Areas of Guatemala
Project GU-TI038-ATN/KE-9514-GU
Inter-American Development Bank (IDB) financed Fundación Solar, Guatemala to develop the projects
GUATEMALA

Photo credits: IDB

Service: Electricity provision to residential sector in 3 isolated rural communities
System/Generation: Off-grid micro hydroelectric generation

Fundación Solar is a not-for-profit non-governmental organisation that has demonstrated leadership during the last years in facilitating and advancing policies for renewable energy and water. It has worked in the identification of policy gaps with a bottom-up vision, making more visible to the governments the needs from the poor and environmental issues. Fundación Solar initiated its operations 20 years ago implementing renewable energy and appropriate technology projects applying an integral multidisciplinary approach in energy, water, environment, risk reduction management, governance and municipal strengthening. The results of these efforts have positioned Fundación Solar as a renowned organisation locally and internationally, focusing its work in the development of local capacity of governments and civil society.

The Challenge
Promote the use of renewable energy in remote rural communities, improve quality of life, stimulate productive uses of energy, increase the value of local goods and contribute to poverty reduction. Despite the fact Guatemala has a national electricity coverage of 86% (as of 2012) several communities are located in areas where access to electricity might be delayed due to relief barriers, low capacity to pay for the services and lack of transmission infrastructure.

The Solution
Promote access to electricity through small scale hydro power systems. The first successful step was to obtain financial and technical support from the IDB to prepare three pre investment studies for the communities of Jolom Ijix, Seasir and Las Conchas.

The projects were later supported by the Government of Japan that financed the construction of the three projects. Fundación Solar helped the supervision of all activities including the sustainability scheme designed in agreement with the communities for the definition of tariffs and individual contributions (each user covered its costs for connection to the minigrid systems). No difficulties have been encountered for receiving tariff payments as of today.

Case study 3

Ikeji- Ile Ijesha Mini Hydro-Power Project
Unido-Regional Center for Small Hydro-Power in Africa
NIGERIA

Photo credits: UNIDO/ICSHP/Naseni/Ikeji-Ile-Ijesha




Service: Installation of Unido/Naseni (National Agency for Science and Engineering Infrastructure) fabricated cross-flow turbines for electricity generation to provide reliable power to Ikeji-Ile-Ijesha, State of Osun, Nigeria.
System: Cross-flow turbines for off-grid power generation.
Generation: 70 kW

The Unido-Regional center for small hydro-power in Africa (UNIDO-RC-SHP), Abuja, Nigeria is an Agency of UNIDO established to facilitate programmes and projects related to renewable energy technology with particular focus on small hydro-power within the African region.

The Challenge

Traditionally the people of Ikeji-Ile/Ira engage in agriculture and produce sufficient food, as well as, cash crops such as raw materials for agro-allied industries. A large segment of the population are traders and artisans. These products are consumed and sold as raw materials either for food or for other factories to process outside the community. The major problem has been the epileptic nature of the power supply to the community by PHCN (Power Holding Company of Nigeria). Youths are therefore migrating to cities.

It is therefore necessary to source a steady power supply to the community. The state of Osun government wants to set up artisan village centers, ICT center etc. with the steady supply of power from the mini hydropower.

The Solution

The State of Osun government mandated the UNIDO-RC-SHP to carry out a detailed project report (DPR). This was completed in August 2008.

The Unido-Vienna in conjunction with National Agency for Science and Engineering Infrastructure (NASENI) and UNIDO-RC-SHP Abuja fabricated the cross-flow turbines in Nigeria and donated it to the project, while the State of Osun government funded the civil works component.

From the inception of the project, the community leaders (Obas and Chiefs), women organisations and youth organisations were involved in the implementation of the project, through consultations, meeting and the decision making on the project. The project is at an advanced stage of construction and will be completed by first quarter of year 2014.

Case study 4

Rosenheim
Smart Hydro Power
GERMANY

SMART HYDRO POWER

Photo credits: Photo SMART

Service: Test site for submerged turbine for fast running rivers in Latin America, Asia and Africa
System: Submerged turbine grid connected at low voltage grid
Generation: 250 Watt to 3000 Watt – depending on water velocity

Smart Hydro Power develops, designs, fabricates and commercialises pico hydrokinetic systems.

The Challenge

Most tropical rivers show extreme variability in depth (+/- 8m), velocity (+/- 2 m/s or 200 %) and debris content. Smart has experienced these variations during site tests in Indonesia and Peru where shallow rivers overnight grew to streams that could not be crossed or entered. Most companies are therefore not offering any products for small, fast running rivers. Designing a hydrokinetic turbine that withstands these conditions is a special challenge.

The Solution

Smart Hydro Power has experienced real life, on site challenges in Peru (Marisol) and Indonesia (Sadap) in regions with highly volatile rivers and strong debris impact during floods. The experience was rather positive with regard to the transport and the installation in these remote areas which worked quite nicely. No crane was needed during installation and all works were done by local people with locally available tools. But the originally installed floating turbine had shown severe difficulties with strongly increasing water level during flood conditions. Due to the variation in anchor force the unit started declining and could therefore no longer withstand the debris.

Therefore Smart Hydro Power optimised the existing floating turbine for river conditions as they can be mostly found in tropical rivers. The generator is built axially into a diffusor. Thereby the diameter of the rotor is kept at 1m with minimised drag force in the water. The mono-float and debris protector are designed with minimal deflector surface so debris passes by. As the turbine is anchored with one single steel cable at the bottom of the river or at the river bank larger debris may deviate the unit shortly before it turns into the ideal flow position again. Unlike the floating turbine the submerged turbine stays with increasing water level and velocity at a defined water depth and velocity – the flood and most of the large debris passes over the turbine.

The turbine has been installed in April 2013 and has been working since then. The river Inn descends from the Alps and is one of the few German rivers with similar conditions as the rivers which descend from the Andes in Latin America or the mighty mountains in Indonesia. During flood conditions in June 2013 the Inn increased by 6 m and showed velocities up to 3.5 m/s. When examined in August 2013 the turbine showed signs from debris impact at the protector but was workable. Since then the debris protection has been enforced to withstand higher forces. The submerged turbine requires cleaning every four to twelve weeks depending on river conditions. As this can be done without fully de-installing the turbine, the expected load factor of the unit stays above 90%.

The submerged turbine has already been installed in Nigeria in December 2013 will be installed in May 2014 in Brazil and Peru.

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About ARE (www.ruralelec.org) :
ARE is an international business association representing the decentralised energy sector working towards the integration of renewables into rural electrification markets in developing and emerging countries.

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