Potentials for Renewable Energies in Sri Lanka

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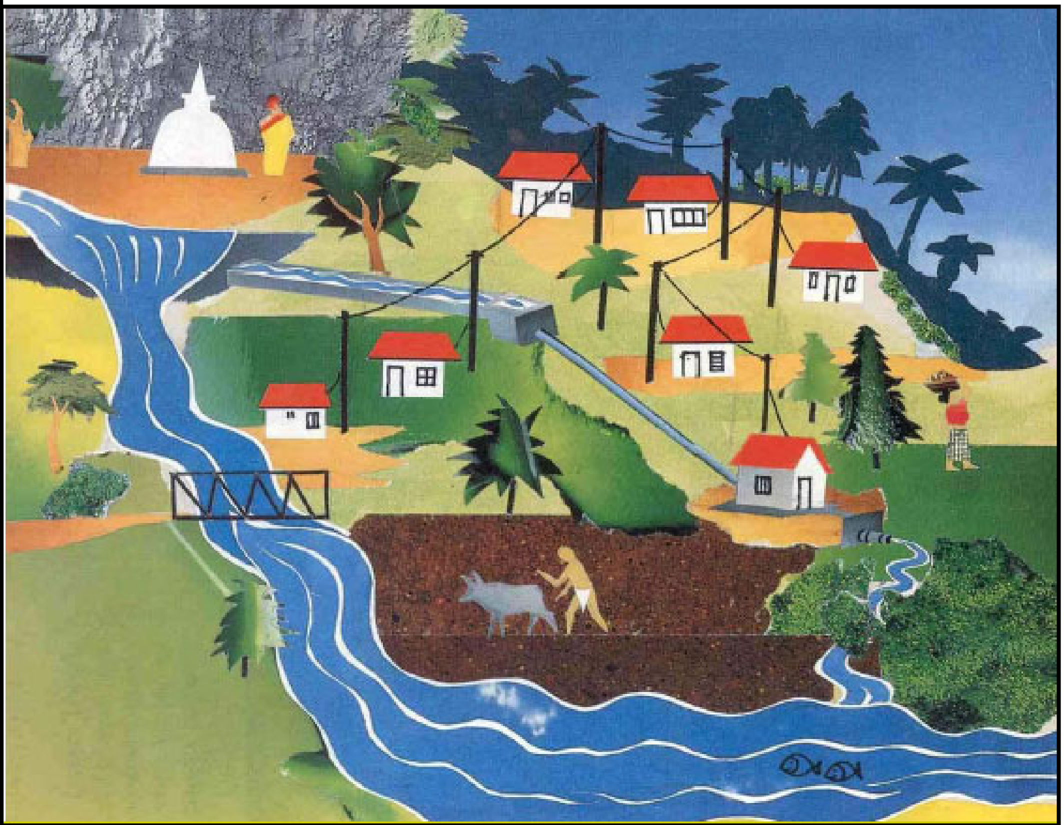

Extension Possibilities to Harness Small- and Micro Hydropower in Sri Lanka

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Foreword

"All is born of water; all is sustained by water."
Johann Wolfgang von Goethe

We know the physical term "Resonance", however, we find similar phenomena as well in biology, psychology and philosophy – and therefore, we can apply the laws of resonance just as to the relation between all the water of our earth and us human beings: To get in resonance with somebody or something, one has to broadcast appropriate signals of which contents can be accepted and replied.

And how do we treat our daily water? We take it for granted! We disregard and waste it thoughtlessly; we reject it in terms of taste and like it only with external additives such as coffee, tea or lemonade; we are not affected personally by the soil contamination in the cultivation; it must be available always and inexpensive, without taking the necessary manipulations and naturally unfavourable treatments in account; we completely don't care whether it has a future – forgetting about our children and we appreciate our own comfort more than respect the element water.

Which reactions do we expect? How long do we want and are able to persist in the opinion, that we stand above the Creation instead of feeling again, that we are a part of it, a guest of this earth and that without following the appropriate rules we soon will be kicked out by our "Mother Earth". Or would you tolerate a guest, who steals your reservoirs, pollutes and poisons your rooms and finally walls up your windows and exploits your last strengths?

Just express thanks for your good glass of water, be pleased about the refreshing rain and enjoy a walk by the sea or a river! This is the first step to restore a good resonance between you and the water.

To work together with the nature in a win-win situation, we still need to comprehend it more!

This is a water crystal of water that was exposed to the word "Peace".

Acknowledgement

Long since I believe the following:

- All I need to know does reveal to me.
- All I need comes to me.
- Everything is good in my world.

I feel big pleasure and happiness to gather here knowledge and to make it available to those walking on the same path.

I aim this dedication to all the people who showed me that what I know: to my parents, to my loves, to my friends, to my teachers, and the Divine and Infinite Intelligence, to channel through me that what the others need to know.

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Furthermore, I express my gratitude to all whose documents made the production of this book possible. This includes Dr. Nishantha Nanayakkara, Head of the Small Power Developers Association in Sri Lanka, his workmate Racit and further, Sunith Fernando and his workmates from the ITDG Asia and the crew of the Energy Forum, Sri Lanka. Further, I express my appreciation also to the Energy Conservation Fund, especially to Mr. Harsha.

Additionally, I feel sincere thanks to Hanspeter Leutwiler from the Association of Small Power Plant Owners (ISKB) for making needed information available to the right time.

Let me thank as well Dr. W.M.S.R. Weerasinghe, Eng. Sanjeeva Witharana and the entire staff of the Department of Mechanical Engineering of the University of Moratuwa for their friendliness and help.

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Especially Melanie Schrenk, who we met fortuitously in the office of the ITDG in Colombo plays the most important role for me. She organized meetings with hydropower specialists in Sri Lanka, arranged excursions to micro hydropower stations in the central area and helped me to find the right literature for this thesis.

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Executive Summary

Sri Lanka has been an agricultural country for more than 2,500 years. Still, most village folk are involved in cultivation as a livelihood. She continues to be an island of villages in rural landscape with 30% living in urban areas. Furthermore, 62% of the inhabitants do have access to the national grid while the electrification rate through all means is about 68%. In remote areas without electricity kerosene lamps for lighting or car batteries, which they have to recharge sometimes several kilometres away are used for minor electrical appliances such as television or radio.

The country has an installed capacity of about 2,000 MW (in 2004) with energy consumed by the different sectors (domestic 41%, industrial 37%, commercial 22%) and a forecast of 8% of annual growth of electricity demand. In comparison, the total installed capacity of Swiss or Germany is about 17,000 MW or 115,000 MW. Having exploited the techno-economically and ecologically viable part of more than the half (1,140 MW) of her commercial major hydro capacity, Sri Lanka is now looking at costly non-hydro sources of power. The reason is the long drought in 1996 in hydro reservoir areas which resulted in power cuts up to six hours a day. The inadequate owner forced the government- monopoly Ceylon Electricity Board to increase electricity generation, mainly through use of expensive thermal and gas resources. However, cost of electricity is a key element in attracting foreign investments into the island for its economic development. Furthermore, the use of imported fuel caused and is still causing electricity price increases and unfavourable environmental effects. This prevailing energy crisis in Sri Lanka is a manifestation of more deep-rooted problems in the governance and development policies. These developments emphasize the need for renewable energy sources which have also the advantage of serving the poor in remote, off-grid areas. This is very important in a country where over 50% of the population receive government subsidy, 70% live in rural areas and nearly half of these without grid-electricity or sometimes even road access. In Sri Lanka, hydropower would continue to be the main and the cheapest source of electricity generation in the medium term. Therefore the development of small hydro (up to 10 MW, SHP) and medium hydro power plants (up to 25 MW), having altogether an estimated exploitable potential of 450-500 MW, has been gaining more and more momentum in the past 15 years. However, it should be promoted with an increased intensity and also took in consideration in Sri Lanka's energy expansion plans for the future.

Principal Results

The country's main concern in the moment is to meet the growing demand of the industrial and the urban commercial sector. In countries with available water resources the electricity demand is met either by constructing only large power plants or by building small and micro hydro power (MHP) stations in rural and remote areas to supplement fewer large ones and so better use all available resources without harming the environment. Many countries, including the more developed ones like e.g. Swiss, Austria, Sweden or Norway are finding the second alternative more attractive. Fortunately, the geo-climatic conditions in Sri Lanka's wet zone is characterised by persistent rainfall lasting for nearly nine months of the year and by a large number of small but steep streams. Therefore, Sri Lanka has a relatively high potential for small-scale hydro power compared with her present installed nationwide capacity. Unfortunately, this decentralized source of energy is not considered to meet the country's major energy demand, even if there is a total estimated potential of about 500 MW. It has been estimated that there are about 200 MW of small water power sites up to a capacity of 5 MW and a further 250-300 MW sites between 5 MW and 25 MW. This total potential of around 500 MW is over 25% of the island's installed grid capacity as at 2003. Besides reactivating the older ones, it would be advantageous to construct many new small or off-grid micro hydropower stations.

But according the United Nations University, the expansion of hydropower for the coming 20 years is expected to be around 220 MW in major development and 200 MW of small hydro, which does not yield firm power. Therefore, only coal and petroleum oil thermal plants appear for them to remain as the only viable electricity generating options. Additionally, the Finance Minister of Sri Lanka Dr. Sarath Amunugama said in one speech in 2004, that the "plan is to raise supply from SHP units of 10 MW to a total of 300 MW by 2008."

Nevertheless, the Ceylon Electricity Board (CEB) does mainly consider thermal sources in their electricity generation expansion plan for the period 2003 – 2017. They try to reduce the actual provision of hydropower in the electricity sector. The CEB is the monopoly power supplier in Sri Lanka and there is no independent power sector regulator. That means, that no other entity is allowed to produce power for sale to a third party.

The Government has so far undertaken two projects with the assistance of the World Bank to promote small hydropower. One is titled The Energy Services Delivery Project (1997-2002) and the other Renewable Energy for Rural Economic Development (RERED). The ESD Project was instrumental in the installation of 18,600 solar home systems (totally 875 kW), 56 off-grid Village hydro projects (aggregate capacity of 574 kW) benefiting 2,800 homes and 15 grid-connected small hydro projects generating a total of 31 MW.

The RERED Project actively supports Sri Lanka's vision of expanding rural electricity access to at least 75% by 2007. The project builds further on the demand driven market based approach initiated by the ESD Project and the collective capabilities of many stakeholders. Up to date there are 21 grid-connected small hydro projects with an aggregate potential of 58 MW and 68 off-grid village hydro projects (748 KW) approved and in development.

Nowadays, especially because of the ESD and RERED project, micro hydropower for off-grid electrification is getting more and more attractive. In November 2003 for instance, there were 161 off-grid micro hydro power (MHP) stations with a total capacity of 1622 kW in operation providing basic electricity needs of 3,687 households. Even if the power outcome is relatively low this is seen very successful due to remarkable achievements in terms of the number of units and households electrified. It is estimated that there are still about 1.023 micro hydro power off-grid locations having an aggregate capacity of about 41.5 MW. This could serve at least 100.000-200.000 households in remote areas to decrease the total number of about 2 million un-electrified households nationwide.

There is a long history of small-scale hydro plants in Sri Lanka starting in 1887 when the country was then known as Ceylon. Until 1959, there were more than 350 hydro plants installed. With a combined total capacity of 10 MW they were providing mechanical and electrical power for the country's tea plantation factories. None of them were connected to the national grid. After the early 1960s many of these schemes fell into disuse because of grid extension.

During the last years a sudden increase of MHP development activity was recorded. This is due to the growing interest among the Sri Lankan government, multinational donor agencies, private sector institutions and local and international NGO's. For example the ESD and RERED project financed by the World Bank had a big impact in the MHP sector. These kind of actions made the wider replication of these micro hydro community based electrification experience possible. But this increased activity created also a worsening in quality in the recent MHP systems and services. This could endanger the whole concept if no appropriate actions are taken.

"An investigation by ITDG (Intermediate Technology Development Group, a NGO) and the Energy Forum carried out to identify ways and means to overcome this, through a series of workshops with key stakeholder of the sector namely the off grid micro hydro electricity consumers, project developers, equipment manufacturers and suppliers, and provincial council officers, has revealed the urgency for the setting up of a regulatory standards, building technical capacities of the manufacturers, and the adoption of technological developments in other countries, as some of the timely needs of this sector."

The cost for a new installation of a small hydro station is site-specific and varies from US$1,200 -3,000 per installed kW depending whether the turbine if it is manufactured locally or not. The cost for refitting old small hydro systems depends also from the location and varies from scheme to scheme. There is a total number of Old Estate Sites located mainly in the plantation sector.

Even if the total potential for small-scale hydropower (up to 5 MW) is around 200 MW, compared with the islands' actual installed capacity (2,000 MW), it offers a viable source of energy to supplement Sri Lanka's electricity demand. Its field is more located in rural areas without access to grid electricity or grid connected industries in the plantation sector, who once abandoned their small-hydro facilities because of CEBs grid expansion activities.

Potential Type	Potentials in Sri Lanka
MHP up to 100 kW	41.5 MW (1023 locations)
SHP 100 kW - 5 MW	150 MW (~400 sites)
SHP 5 MW - 10 MW	50 – 100 MW
Total SHP 0 - 10 MW	**About 240 – 290 MW**
Medium Hydropower 10 - 25 MW	**200 – 250 MW**

Table 1: Summary of Sri Lanka's Recorded Small-Scale Hydropower Potentials (2005)

Please note that the data for SHP is partly from the year 2000. The total national potential would certainly be higher than the present estimate, which is based on the data available to the author. Meanwhile it could also be that some planned SHP plants under the ESD project or even RERED are contributing to the national grid. Therefore, the author estimates the recorded potentials for SHP between 240 MW and 290 MW.

There are certainly still many low head locations (irrigation systems) which are not considered in the previous assessment surveys. Nevertheless, there are enough sites nationwide recorded, especially MHP locations waiting to be harnessed.

1 Abridged Version for Decision Maker

1.1 Objective of this Abridged Version for Decision Maker

The objective of this report is to provide a Comprehensive and Authentic Reference Document by gathering Sri Lanka's total small-scale hydropower (up to 25 MW) resource development potentials. Micro hydropower (up to 100 kW) for rural electrification plays herby the central role. It is also aimed to report the present status of the utilization of small hydropower resources and to make proposals for the future small hydropower development in Sri Lanka.

1.2 Findings

Sri Lanka, the former Ceylon is a tropical island situated in the Indian Ocean to south-east of India covers an area about 65,610 square kilometres with a coastline of 1,340 km. The estimated population as of 2004 was about 19.9 million with the highest population density in the south-west sector.

The country's economy heavily depends on her water resources. The reason is the rain-fed and irrigated agriculture contributing to 22% of exports, and the industries that contribute to 75% of export which are operated by the national grid electricity.[1]

Sri Lanka has a variety of climates dependent upon the monsoons and altitude. There is a division into three districts areas, the wet zone, i.e. the south-west sector, the dry zone of the north and east, and the up-country or south-central highlands. In the dry zone, the annual rainfall varies from about 5 mm to 1,000 mm, where other parts experience intermittent and heavy rains with rain falling up to 5,000 mm annually.

Sri Lanka's power sector is suffering from severe problems. There have been serious shortages of electricity in the past five years. This is on the one hand due to delays in completing investments in power stations and infrastructure to meet growth in demand and on the other hand due to irregular monsoon rainfall and bad administration by the Ceylon Electricity Board. E.g. they purchased plants which do not function properly. Emergency measures to increase the amount of available power, through, for example, the installation of diesel generators were carried out. They have reduced the shortages but this has also led to serious increases in electric prices.[2] Therefore electricity prices on the island are among the highest in South Asia, and power supplies remain unreliable and voltage fluctuations are significant. Despite the high prices the power sector is operating at a loss.

The total installed capacity of power plants in Sri Lanka is about 2,000 MW, 58% of which is hydro-based. The rest is fossil-fuel based using small steam turbines, gas turbines and diesel engines. Fossil fuel options, especially coal are expected to account for a large proportion of new generating capacity in Sri Lanka. About 41% of electricity consumption is accounted by households, 37% by industry and the rest by commercial consumers.[3]

In comparison, the total installed capacity of Swiss or Germany is about 17,000 MW or 115,000 MW.

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[1] Somasekeram, 1997

[2] See *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

[3] Compare ibid.

The existing generation system in Sri Lanka is predominantly based on hydro power. It is the main indigenous source of primary commercial electrical energy with an estimated potential of about 2,500 MW, of which more than half has already been exploited. 58% of the total existing CEB system capacity, which is about 2,000 MW (in 2004) is installed at 15 large hydro power stations with a total amount of 1335 MW and an additional 56 MW small hydro installed capacity (2002). The rest of about 600 MW is fossil-fuel based systems. During the period 1972 to 1990 hydropower was producing up to 95% of the country's electricity. This amount decreased to 46% in 2000 and 40% in 2002. This is due to several droughts forcing the government to make Sri Lanka more independent from hydropower and more dependent from hydrocarbons.[4]

More than 45% of the islands total large hydropower potential is already harnessed. These are mainly multi task projects of controlling floods, supplying of irrigation water and generation of power. According to USAID "all the techno-economically feasible hydro-power potential has been identified and the balance available, has been identified as approximately 1,268 MW. Out of which 1,066 MW is the estimated potential that can be developed. The balance may not be viable to develop due to environmental and economic barriers."[5]

Particulars	In MW	%
Estimated Total Hydropower Potential (USAID/SARI, 2002)	**2,423**	**100**
Developed Total (USAID/SARI, 2002)	**1,137**	**46**
Techno Economically feasible for Development (USAID/SARI, 2002)	**1,066**	**43**
Large Hydropower under Construction (USAID/SARI, 2002)	**70**	**1,6**
Committed for Future Hydropower Projects (USAID/SARI, 2002)	**150**	**6,1**
Expected (USAID/SARI, 2002) Total Hydropower Development by 2012	**1,663**	**68**
Expected (United Nations University, 2002[6]) Total Development for *Large Hydro* by 2022	**220**	**~9**
Expected (United Nations University, 2002) Total Development for *Small Hydro* by 2022	**200**	**~8**
Expected (Finance Minister Sri Lanka) Total Development for *Small Hydro* by 2008	**300**	**~12**

Table 2: Sri Lanka's Total Installed Large Hydropower Capacities & Remaining Potentials

Additionally, there are actually about 100 MW of installed small hydropower capacity feeding electricity to the grid. More information about the actual situation and prevailing potentials in the small-scale hydropower sector is available in chapter 6.

[4] Compare *Longterm Generation Expansion Plan,* CEB 2003.

[5] Adapted from *Regional Hydro-power Resources: Status of Development and Barriers*, For United States Agency for International Development (USAID) under South Asia Regional Initiative for Energy (SARI), prepared by Nextant SARI / Energy, 2002.

[6] *Role playing game approach to introduce complex water resources decision making process*, Srikantha Herath, United Nations University, 2002.

Opinions about the future of water power development in Sri Lanka are different. According the United Nations University, the expansion of hydropower for the coming 20 years is expected to be around 220 MW in major development and 200 MW of small hydro, which does not yield firm power. Whilst United States Agency for International Development (USAID) and South Asia Regional Initiative for Energy (SARI) expects about 500 MW of new hydropower stations developed in the next seven years. Additionally, the Finance Minister of Sri Lanka Dr. Sarath Amunugama said in one speech in 2004, that the *"plan is to raise supply from SHP units of 10 MW to a total of 300 MW by 2008."*

However, fact is that there are still enough both large and small hydro potentials which could be harnessed to meet the islands increasing energy demand. The objectives of the hydropower policy should try to achieve the following:

- **To utilize the existing small-scale water resources and to ensure the returns so that the private investors are encouraged.**
- **To ensure the maximum amount of renewable energy availability needed for economic activities.**

Table 3 Objectives of Hydropower Policy, source: Author

Small hydropower is a very important source of energy, especially in Sri Lanka, the reasons being:

Advantages of Small Hydropower especially in Sri Lanka
• There are plenty of rivers and streams in the hills. • The national power grid extends to only a limited area. • Low investment capability of the people • Scattered settlements. • Low purchasing power of the people. • Low electricity consumption of the people.[7]

Table 4: Advantages of Large and Small Hydropower

The expansion of hydroelectric power for the coming 20 years is expected to be around 220 MW in large hydro development and 200 MW of small hydro. Various power generation experiments such as wind energy, micro-hydro and small hydro and solar energy has been tried but found to have a small impact on the country's energy demand and supply scenario. Therefore, only coal and petroleum oil thermal plants remain as the only viable electricity generating options in the eyes of the United Nations. The CEB has identified to cater coal based power generation for immediate power needs of Sri Lanka. But CEB is unable to proceed because of strong protests from environmental groups.

Total system loss of total generation in the interconnected grid amounted to approximately 21% in 1999. The cost of un-served energy through electricity shortages for the Sri Lankan system is estimated to be US$0.66 /kWh for planned interruptions and US$1.06 kWh for unplanned interruptions. These costs are very high compared to the cost of

[7] Adapted from *Financial Guidelines for Micro-Hydro Projects*, ITDG Nepal publications, 1997.

power supplied to industry by CEB ranging from US$0.078 /kWh to US$0.083 /kWh. The prevailing electricity shortages and the incapability to meet the country's electricity demand led Sri Lanka to an energy crisis.

"The energy crisis in Sri Lanka is a manifestation of more deep-rooted problems in the governance and development policies. The protests against energy development find sympathetic audience with a public that distrust the CEB which had a monopoly on energy and carried out its expansion with little dialog with public or concerned parties. This distrust extends to government in general charged to be self-serving and incompetent. The problem is exasperated by the decline of the power and morale of engineering community, which had its golden era since 1940s to late 1970s. With the advent of open economy since then, most of the important infrastructure development has been carried out with foreign grants/loans where the design, construction and consulting had been carried out by the engineers from donor countries, that delegated local engineers and technology to a minor supporting role. This environment is not conducive to find and implement indigenous solutions and is a far more serious problem."[8]

1.3 Physical Feature and Climate

Sri Lanka's central and south-western parts are characterised by heavy and continuous rainfall and an uneven terrain with steep and rolling landscape. This geo-climatic condition has led to the formation of a great deal of streams, radiating from the upper reaches of the mountains and merging downstream to form some of Sri Lanka's major rivers, such as Mahaweli Ganga, Kelani Ganga and Kalu Ganga. These major rivers as well as small streams in the upper areas offer considerable potential for hydroelectric power development.[9]

1.3.1 Relief

A central highland massive are in the southern half of the island and compromise a series of plateaux and peaks, the highest of which is 2,524 metres. While in many places the topographical feature is separated by well marked steep slopes the intermediate zone in turn is enclosed by a low-lying zone of lands. The shores are mostly sandy beaches but also lagoons surround the island.

On the basis of elevation and landforms, Sri Lanka could be divided approximately into the following five topographical areas:

- The Central Highlands
- The South-west country
- The East and South-east country
- Northern lowlands
- The coastal region

[8] Quotation from *Role playing game approach to introduce complex water resources decision making process*, Srikantha Herath, United Nations University, 2002.

[9] Please note that the quality of some illustrations in this chapter is sometimes not high. This is due to the author's easy and fast scanning method through a digital picture camera during the period of literature enquiry.

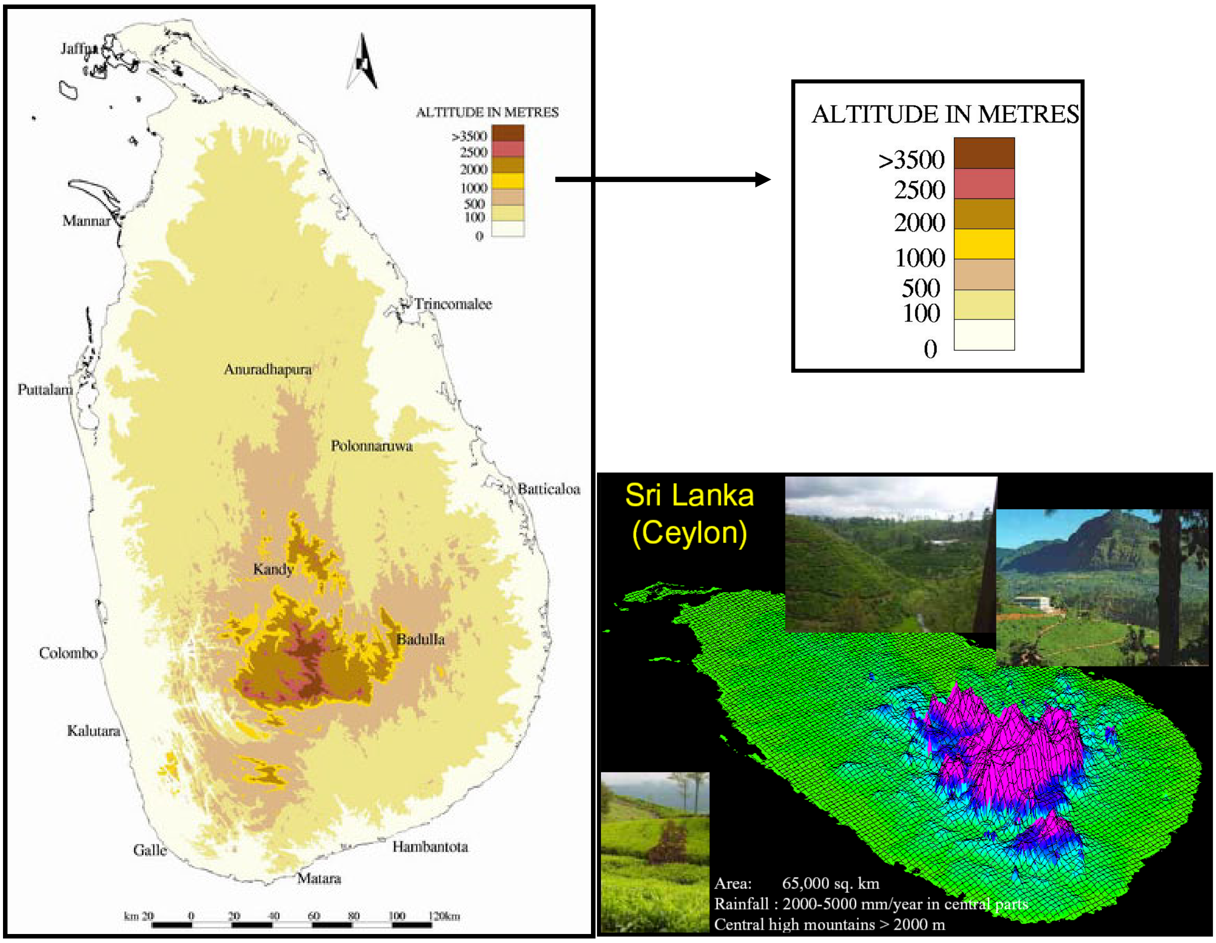

Figure 1: Schematic[10] & Computerized Representation of the Surface Configuration[11]

Areas of interest concerning hydro power development are the Central Highlands and the South-west country. The Central Highlands could be subdivided into two major landforms, on the one hand the Central Massif and on the other hand the Dumbara and Bulutota Massif which are detached parts of the Central Massif.

The Central Massif is a fairly compact unit bounded on the south by a mountain wall. On the north there is the traverse valley of the Mahaweli Ganga from Minipe to Kandy. This Central Massif consists of a *central backbone* of high plains and peaks which run from Bopatalawa to Pidurutalagala. Among the high plains of this backbone are, Elk Plains (Mipilimana), Moon Plains (Hawaeliya), Horton Plains (Bopatalawa), Kandapola Plains (Sitaeliya) and Ambewela Plains. While Pidurutalagala is with 2,524 m the highest point of Sri Lanka, Totapolakanda (2,357 m) and Kirigalpotta (2,395 m) are the other two peaks in this backbone area. Hatton (Ambatalawa) Platea and the Uva basin are the other two important elements of the Central Massif.

It is raining significantly in the South-west part of Sri Lanka. Fig. 2 shows a generalised rainfall map of Sri Lanka.

[10] Source: http://iri.columbia.edu/~lareef/wcsl/SriLankaMay2003Weather.html [2004.12.17]
[11] Source: *Role Playing Game Approach*, J. Valasquez, S. Herath, p. 207, 2002.

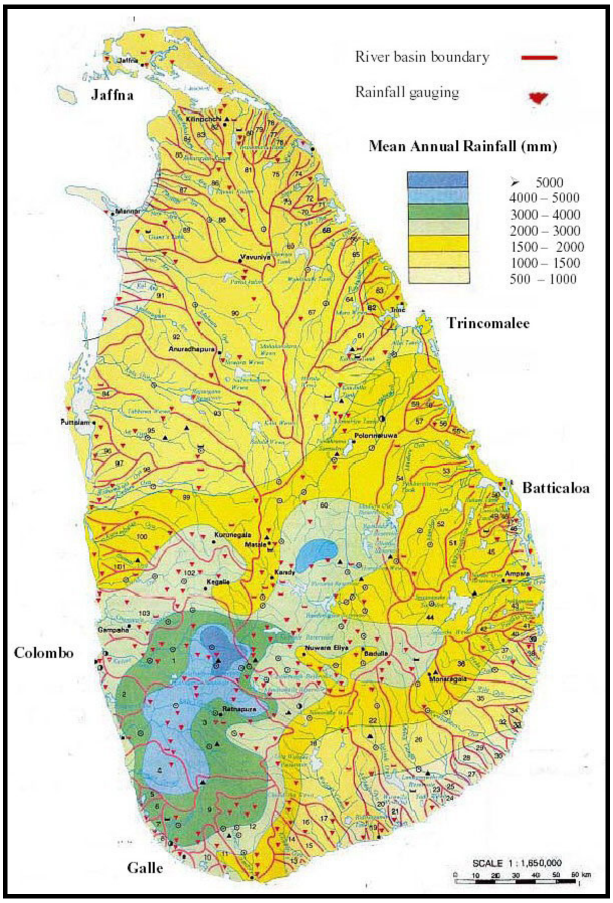

Figure 2: Generalised Rainfall Map of Sri Lanka, source Somasekeram (1997)

1.3.2 The Rain Climate

The country has a variety of climates dependent upon the altitude and three types of rain climate, the monsoonal, convectional and depressional[12]. There is a division into three districts areas, the wet zone, i.e. the south-west sector, the dry zone of the north and east, and the up-country or South-central highlands. In the dry zone, the annual rainfall varies from 1015 mm to about 5 mm, where other parts experience intermittent and heavy rains.[13]

Monsoonal rains take place during the period of the two contrasting Asian monsoon wind systems, namely the south-west (SW) and north-east (NE) monsoon. This monsoonal rain is responsible for the annual rainfall. Convectional rain takes place during the transitional period from one monsoon to another, mostly in the afternoon and evening and appears to be experienced anywhere over the island. Low pressure rains are more regular in the second monsoon period of October and November. They are responsible for a large part of the rainfall during these two months. Therefore, Sri Lanka's rain climate is described by four distinct seasons:

[12] Depression indicates area of low pressure.

[13] See *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999, p. 6.

1. March – mid May : First inter-monsoon season
2. Mid May – September: South-west monsoon season
3. October – November : Second inter-monsoon season
4. December – February : North-east monsoon season

According to this classification, *"the two monsoons last over 62.5% of the year while intermonsoon seasons account for the balance. However, under no circumstances does the monsoon regime over Sri Lanka exhibit homogeneous climate conditions over the whole island. Besides the fundamental difference of the structure and rainfall conditions in both the monsoon seasons, the general climate also exhibits a considerable spatial differentiation as a result of the Central Highlands. Although these highlands have no great vertical extension (highest elevation 2,524 m at Piduratalagala), they form an* orographic barrier *across the path of monsoonal air masses and winds. Thus, the highlands not only perform the role of climatic-shed, but also establish the regional differentiation of the Highlands into windward and leeward side, including the flanking lowlands."*[14]

Besides this larger regional consequence, there is also the micro-regional relief of the Central highlands modifying the windward and leeward side climates. This results sometimes in far-reaching small-scale difference from the widespread, large-scale climatic circumstances.

In spite of the small area of the island there is an extraordinary variation in precipitation, *"amounting to over 5,500 mm in the wettest part and about 1,000 mm in the driest area. Thus the absolute range of rainfall amounts to 4,500 mm."*[15] The south-west part with the Central Highlands is clearly the wettest area of the country (See also rainfall map, Fig. 2). Within the islands south-west sector the absolute maximum of precipitation is in the western hills of the Highlands – at lower altitudes between 300 m and 1000m (Maliboda, Watawala and Ginigathhenna). From this small area of highest rainfall precipitation continues to decrease over 1000 m reaching about 2000 mm on the high plains around Nuwara Eliya with an altitude of proximately 2200 m. However, rainfall is more gradual towards the coastal plain in the south-west.

Obviously, the rainfall regime in most sections of the mountainous area of the island, especially in the western hills is characterised by a constant and well distributed pattern for about nine month of an average year. This wet climate together with the uneven ground has formed many streams radiating from the mountains. These conditions offer considerable potential for hydroelectric power development, not only large hydro power but also small-scale ones.

1.4 Small and Micro Hydropower Potentials in Sri Lanka

Micro hydro was almost from the beginning of the tea industry the main source of power for its factories. Many were intentionally located close to streams and rivers to take advantage of the energy potential. In the late 1940s large-scale hydro systems to supply the national grid started to be more and more common. So most of the units gradually went out of use and the advantages of micro hydropower appeared to decrease. At this time energy supply was beyond of demand. Therefore, the tea estates were identified by the government as

[14] Quotation from ibid.

[15] Quotation from ibid, p. 7.

potential customers of grid electricity. With transformers provided on favourable terms it was aimed to encourage factories to change from micro hydropower to grid electricity. Later, by 1985 only 5% of the initial micro hydro units were still operating.[16]

Nearly all tea estates in Sri Lanka had abandoned their small hydropower plants by the 1970s and were acquiring electricity from the Ceylon Electricity Board. Increasing petroleum costs in the following decades made the rehabilitating of these old plants, and constructing of new ones feasible but it is necessary to replace obsolete electro-mechanical equipment and repair extensively civil work components.

1.4.1 How does it work?

Micro hydro schemes are normally designed to operate for a minimum of 20 years if they are properly looked after. They are usually “run-of-the-river” types meaning that they do not require a dam or storage facility to be constructed. Therefore, this type of hydro power avoids the damaging environmental and social effects which larger hydroelectric schemes cause.

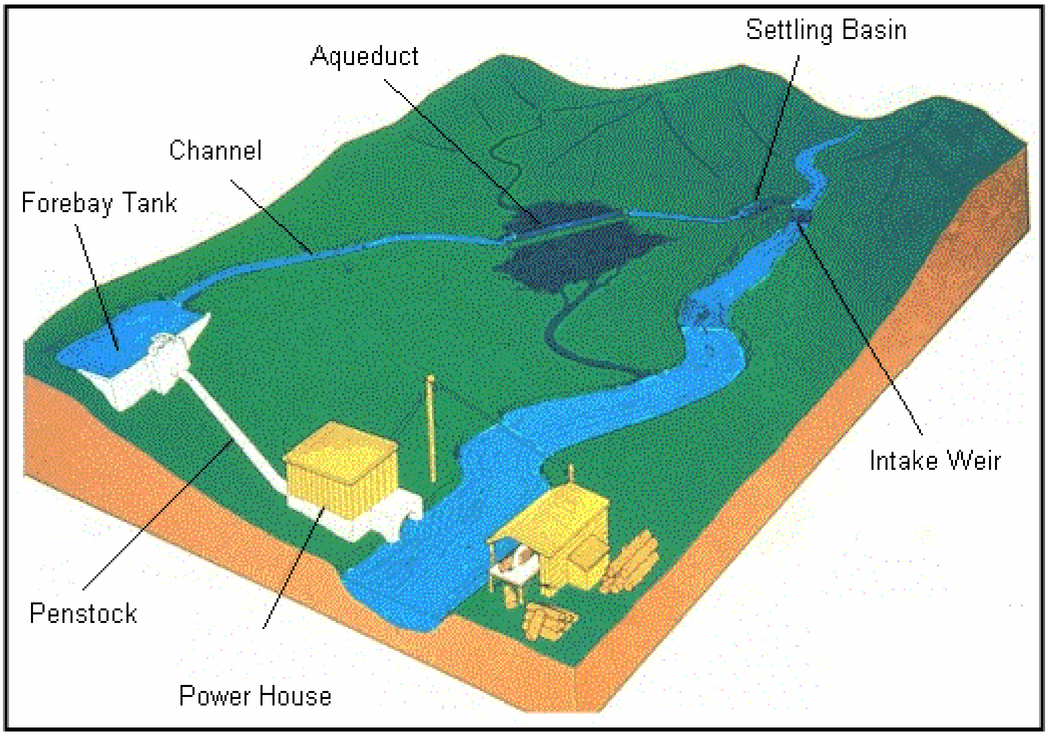

Figure 3: A Typical “Run-Of-the-River“ Micro Hydropower Scheme

They simply channel water from the stream or river through a settling basin, which helps to remove sediment that could harm the turbine. The water is diverted through a masonry or concrete weir built across the stream. The water then flows into the forebay tank where it is directed downhill through a pipe called penstock and “dropped” in to a turbine. This specially designed turbine drives an induction generator, which is a standard induction motor converted to run as a generator. The scheme provides 230 V AC current to households via a distribution line.

According to ITDG the cost for a typical micro-hydro system varies depending on the project. As a guide every installed kW cost around US$1,200. A six kW scheme, which is

[16] According to *Beyond big Dams, A New Approach to Energy Sector and Watershed Planning*, IRN, 1998.

enough to drive an electric mill and provide light for a community of about 500 people, would cost approximately US$7,200. ITDGs experiences show that community capital in form of "sweat equity" and cash, financial credit and improved income makes these schemes economically viable and sustainable.[17]

1.4.2 Actual installed Small-Scale Hydropower Plants

It is to distinguish between small hydropower systems (SHP), which are mostly located in the plantation areas, where grid-electricity has already reached and off-grid Micro Hydro (MHP) systems serving remote areas without grid connection.

In 1995 was the first successful commissioning of a stand alone grid connected SHP plant with 800 kW of installed capacity. By end 1998, three more SHP plants with a total capacity of approximately 1 MW were connected to the national grid. By end February 2000 the total capacity of grid connected SHP stations was about 12 MW.[18]

In 2003, the CEB was maintaining three small hydro plants (Inginiyagala, Uda Walawe and Nilambe) contributing 20 MW to the national grid whilst private small hydro plants connected to the network system amounted around 37 MW. Further 37 MW of private plants were under construction and Letters of Intents had been issued for another 100 MW.[19]

When additionally the RERED SHP projects are implemented in the next years, another 21 plants having an aggregate potential of 58 MW will be connected to the national grid. But this will take some years until all projects are finished. It is yet not clear if these 58 MW were already considered in the CEB Long Term Generation Expansion plan of June 2003 as Letters of Intents. Assuming the ESD projects being already implemented and contributing their potential to the grid, the following estimation can be made by the author:

Generation Type	Number	Total Installed Capacity
Small Hydropower	30-40	100 MW
Micro Hydropower	200-250	~2 MW

Table 5: No. & Installed Capacity of SMH & MHP Stations Estimated by Author (2005)

All together about 30 - 40 small and small hydropower stations with a total installed capacity of about 100 MW contributes to the national electricity network while at least 200 micro hydropower stations with a total installed capacity of about 2 MW serve remote areas in rural Sri Lanka.

1.4.3 Small-Scale Hydropower Potentials in Sri Lanka

Even if the total potential for small-scale hydropower (up to 5 MW) is around 200 MW, compared with the islands' actual installed capacity (2,000 MW), it offers a viable source of energy to supplement Sri Lanka's electricity demand. Its field is more located in rural areas without access to grid electricity or grid connected industries in the plantation

[17] See *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999, p. 6.

[18] Quotation *Grid Connected Small Hydro Power in Sri Lanka*, Dr. Romesh Dias Bandaranaike, International Conference On Accelerating Grid-Based Renewable Energy Power Generation for a Clean Environment, 2000.

[19] Compare *Long Term Generation Expansion Plan*, CEB, 2003.

sector, who once abandoned their small-hydro facilities because of CEBs grid expansion activities.

Estimations concluded, "*that for about 20% of Sri Lanka households (about 640,000 homes), it will not be economic to bring them grid supplied electricity. However, Sri Lanka is rich in renewable resources, such as small-scale hydro, solar, biomass and wind, which could be used to provide power to these isolated communities. These can be community-run systems that offer limited, but reliable supplies of electricity at prices not affected by world fuel market conditions. They generally use technology that can be produced and maintained locally. The main technology used at present is micro-hydro, although other technologically proven options, such as wind-power can also be used. Worldwide interest in small-scale decentralised power sources is likely to make additional options, such solar power and biomass (using specially planted trees) economically viable.*"[20]

Potential Type	Potentials in Sri Lanka
MHP up to 100 kW	41.5 MW (1023 locations)
SHP 100 kW - 5 MW	150 MW (~400 sites)
SHP 5 MW - 10 MW	50 – 100 MW
Total SHP 0 - 10 MW	**About 240 – 290 MW**
Medium Hydropower 10 - 25 MW	**200 – 250 MW**

Table 6: Summary of Sri Lanka's Recorded Small-Scale Hydropower Potentials (2005)

Please note that the data for SHP is partly from the year 2000. The total national potential would certainly be higher than the present estimate, which is based on the data available to the author. Meanwhile it could also be that some planned SHP plants under the ESD project or even RERED are contributing to the national grid. Therefore, the author estimates the recorded potentials for SHP between 240 MW and 290 MW.

There are certainly still many low head locations (irrigation systems) which are not considered in the previous assessment surveys. Nevertheless, there are enough sites nationwide recorded, especially MHP locations waiting to be harnessed.

1.4.4 Different Assessment Surveys carried out so far

Micro hydro has been used considerably to meet the energy needs of most Sri Lankan remote villages possessing hydro resources. The feasibility of this renewable technology was demonstrated in Sri Lanka the first time in the year 1991 by ITDG. By engineering a formal society, the Electricity Consumer Societies (ECS), the MHP stations could be completely managed by the communities of the villages. These ECS deal with the main tasks such as operation, maintenance, collection of the tariff and the responsibilities like overall management of the project, discipline and compliance of the membership to the standards and procedures which are set up by the society leadership. Even the government and the World Bank have accepted the ECS approach, by including village hydro in its Energy Service Delivery Project (ESD).

[20] See *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

Furthermore, ITDG created an enabling environment for the wider uptake of the off-grid rural electrification option through MHP. The interventions were:

- Building capacity at local manufacturer/supplier level, NGO, provincial council and national level,
- project designing, implementing and evaluation, and
- awareness creating at policy formulation level.

Aim of this present report is to support widespread development of Sri Lanka's small hydro resources. That results in a starting point for hydro power developers to identify potential and lucrative sites for further development. For this reason the engineering of a comprehensive database on small-scale hydro sites and their exploitable potential is very important.

Such a data base is already prepared by ITDG, Sri Lanka. *"The direct output of the study is a computerised database on small-scale hydro power sites giving the site location, catchment area, estimated average daily flow, head and the exploitable power potential."*[21] Studies drawn up in the past have provided some valuable information for such a database. The table below presents the details of the references and resource database reviewed and used in the present study.

- *Feasibility Study for the Rehabilitation of Mini Hydro Stations,* Cansult Ltd. 1984. (referred to hereafter as CANSULT study)
- *Sri Lanka Mini Hydro Rehabilitation Project,* Salford Civil Engineering Ltd. In association with Binnie & Partners. The project is carried out under assignment by the Overseas Development Administration (ODA), 1986.

  (Referred to hereafter as the ODA study)
- *Electricity Master Plan* Study, CEB, 1988.
- *An Assessment of the Small Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 1999. (referred to hereafter as the Small hydro study)
- Grid connected Small Hydro Estimations by Private Developers, Dr. Romesh Dias Bandaranaike, 2000.
- *An Assessment of Off-Grid Micro Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 2000. (referred to hereafter as the Micro hydro study)

The CANSULT and ODA Study

The CANSULT study has examined about forty sites for rehabilitation and their feasibility. It presents the technical details in respect of only nineteen sites which were selected for detailed study. Anyway, the potentials for reactivating old schemes are recorded in the Small hydro study from 1999 including the data from the CANSULT study. For this reason the CANSULT study is not considered anymore in this paper. The ODA study was very much a feasibility report which was concerning eight selected small hydro sites and revealed very little about hundreds of other old hydro sites.[22]

[21] Quotation from *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999, p. 2.

[22] Compare *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999.

CEBs Electricity Master Plan Study

The Electricity Master Plan Study conducted by the CEB in 1988 aimed partially to examine the feasibility of rehabilitating SHP plants in the plantation sector. In the early 1970s, the government had nationalised the plantations. At that time, all large plantations were run by two government corporations. While the study revealed that there is potential for:

- development of new sites;
- harnessing the head from irrigation canals, tanks and reservoirs; and
- reactivation, up-gradation or extension of existing sites.

This study did not result in any sustained programme to develop the SHP sector in Sri Lanka. It was estimated that 30 MW of small hydro potential exists in about 60 undeveloped sites while a further 8 MW in about 290 irrigation tanks and reservoir sites. Another 50 MW of small hydro potential could have been tapped in 140 sites.[23]

There are certainly more potentials than 8 MW in Sri Lanka's tremendous irrigation system which are not considered in this study.

The Small Hydropower Study for the Plantation Sector

It is estimated that more than 350 micro-hydro stations (originally engineered by colonial planters to generate electricity and motive power for their plantation industries) had been in operation in the early part of the 20th century. *An Assessment of the Small Hydro Potential in Sri Lanka* written by Sunith Fernando in 1999 *"presents a preliminary assessment of the small hydro potential in Sri Lanka, focussing largely on the plantation sector. It is based on a two-year research study conducted by the Sri Lanka Country Office of the Intermediate Technology Development Group."*[24] Small hydro is meant here to include the full range of capacities up to about 5 MW which is the largest capacity surveyed during *the Small hydro study*

According to Sunith Fernando, there is a total estimated small hydro potential of 97.4 MW in Sri Lanka. *"This estimate <u>excludes</u> the small hydro potential of nearly 50 MW identified by the Electricity Master Plan Study conducted by CEB in 1988. As highlighted earlier, the present study cannot be considered as an exhaustive one that has covered all the sites in the country. In particular, the study has not been able to cover extensively the potential sites in the head range of below 30 m.*[25] *The exploitable power potential has been estimated in the present study on the basis of the ADF*[26] *which may not necessarily be the optimum design flow for the particular site. Taking all this into account, it could safely be assumed that the total exploitable small hydro potential in Sri Lanka might be in the range of 170 MW-180 MW.*[27]

The total number of the surveyed sites is 257. These can be grouped in Old Estate (137), New Estate (71) and Non Estate sites (49). It should be emphasised, that the Small hydro study is focussing largely on the plantation sector.

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[23] Compare *Master plan for electricity supply for Sri Lanka*, CEB, Sri Lanka, 1988.

[24] Quotation from *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999, published in Energy for Sustainable Development, Volume VI, March 2002, p. 95.

[25] Low head potentials in off-grid regions are recorded in the Micro hydro study on p. 22.

[26] ADF is an abbreviation for **A**verage **D**aily **F**low.

[27] Quotation from *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999, p. 31.

Site Classification	Number of Sites	Utilised Potential (MW)	Exploitable potential		Highest Site Capacity (kW)	Lowest Site Capacity (kW)
			MW	% of the total		
Old estate sites	137	6,1	23,668	24,4	1,665	5
New estate sites	71	-	20,723	21,2	1,127	8
Non estate sites	49	-	53,016	54,4	5,192	44
Total	257		97,407	100		

Table 7: Distribution of all sites by classification and capacity[28]

Old Estate Sites contribute with 137 sites 53.3% to the total number. At this locations, there are still or had been hydro plants in the past with a total exploitable potential of about 23 MW including sites belonging to the three classification abandoned, not in operation and in operation. The original old estate installations, in some cases were designed to provide less power than is now needed.

The contribution of 71 surveyed New Estate Sites to the exploitable overall potential is with 20.7 MW 21.2%. These are new locations found within boundaries of the investigated old estate sites in the plantation sector.

Altogether 49 Non Estate Sites were surveyed having a total exploitable potential of 53 MW making 54.4% of the total. These sites are situated outside an estate, mostly on state land.

"Of the estimated potential of 97 MW, nearly 45 MW is found in the estate sector which could generate (assuming a plant factor of ~ 50%) about 200 GWh annually. Full development of this small hydro potential could generate annual revenue of Rs. 600 million within the estate sector assuming an average electricity purchase price of Rs. 3.00 per kWh. Assuming an investment of the order of Rs.90,000 (~ US$1,200) per kilowatt installed capacity, the total investment in this sector would be about Rs.4,050 million (~ US$54million). This leads to a simple pay-back period of about 6.7 years."[29]

Therefore, small hydropower seem to be a financially attractive and large enough investment chance for firms who wish to diversify income generating activities within the plantation sector. Nonetheless, investment in the small hydropower development in the estate sector is yet to gain momentum.

In 209 sites there is the estimated site potential less than 500 kW within 22% of these sites have less than 50 kW and 25% lie between 50 kW and 100 kW. Nearly 70% (48) of the sites in the range from 500 kW to 4,000 kW have capacities between 500 kW and 1,500 kW.

Grid Connected Small Hydropower Estimations by Private Developers

There is also a paper which was presented at the International Conference On Accelerating Grid-Based Renewable Energy Power Generation for a Clean Environment in 2000. This paper was prepared by Dr. Romesh Dias Bandaranaike, who is the president of the Grid-Connected Small Power Developers Association.

[28] Adapted from ibid, p. 27.

[29] Quotation from ibid, p. 31.

"Sri Lanka has a relatively high potential for SHP, compared with the present installed capacity of its electric utility grid. It has been estimated that there are 250-300 MW of financially viable SHP sites up to a capacity of 10 MW and a further 200-250 MW of financially viable sites between 10 MW and 25 MW. This total potential of around 500 MW is over 30% of the installed grid capacity in the country as at end-1999."[30]

It is not clear for the author, where these estimations come from. Unfortunately, attempts to contact to the author were not successful. Nevertheless, these estimations were also included in the total estimated SHP potential in Sri Lanka as they are not contradictory with other surveys. The importance in this paper is not to assess exactly all potential sites with accurate details. This is not possible due to vague potential estimations through desk studies. The main objective is the creation of awareness in different sectors that there are enough SHP potentials waiting to be exploited.

Off-Grid Micro Hydro Study

In 2000, ITDG carried out this off-grid micro hydro potential assessment for the ESD project. The results and newer estimations show a meteorological potential of about 41,5 MW in 1023 sites in 10 districts of the Uva, Central, Sabaragamuwa and Southern provinces. On the basis of 200 W per household this capacity is sufficient to meet the basic power requirements for nearly 180,000 households.

As currently only 68% of the islands households have access to the electricity and it is estimated that about 80% could reasonably be served by grid extension there are still enough off-grid regions in Sri Lanka to be electrified.

Additionally, there is a great difference in the electrification rate among the urban, rural and estate sectors as illustrated in the following table. For example record more urbanised districts, such as Colombo and Gampaha electrification rates as high as 96% and 80% respectively, the rate in the socio-economically backward Monoragala district is only 15%.

	No. of Households	Electrified Households	Electrification Rate
Urban	880,000	836,000	95%
Rural	3,045,000	1,155,500	38%
Estate	275,000	27,500	10%

Table 8: Number & Distribution of Electrified Households in Sri Lanka[31]

According to an investigation conducted by the Energy Conservation Fund on the rural energy demand and supply in the North Western province, 24% of rural households use automobile batteries for lighting or to operate minor electrical appliances like television and radio. Most of the battery users have to travel over 2 km to reach a battery charging centre whilst 40% of them spend over Rs.40 (US$0.6) per month to recharge them.

[30] Grid Connected Small Hydro Power in Sri Lanka, Dr. Romesh Dias Bandaranaike, International Conference On Accelerating Grid-Based Renewable Energy Power Generation for a Clean Environment, 2000

[31] Adapted from *An Assessment of Off-Grid Micro Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 2000

Unexploited off-grid MHP potentials are still waiting to be used especially in the wet area of the island. They can contribute well to the nationwide electrification rate, as in a typical off-grid MHP system only 100 W – 200 W of electrical power is given to each household. This is enough to operate either 3-4 lamps or a television and radio set. Even if the power outcome is relatively low this is seen very successful due to remarkable achievements in terms of the number of units and households electrified. There were for example 161 micro hydro power stations with a total capacity of 1,622 kW in operation providing basic electricity needs of 3,687 households in remote villages. While in 2000 the monthly tariff was about Rs. 100 (US$1.3) per household charged to meet O&M expenses this tariff increased to Rs. 300-600 (US$3 -6) in ESD off-grid projects. The owner and manager of such scheme is the Electricity Consumer Society (ECS) where the consisting members are from the beneficiary families. The ECS deals with the main tasks such as operation, maintenance, collection of the tariff and the responsibilities like overall management of the project, discipline and compliance of the membership to the standards and procedures which are set up by the society leadership.

The table below shows the accelerated growth in the past years of MHP schemes nationwide.

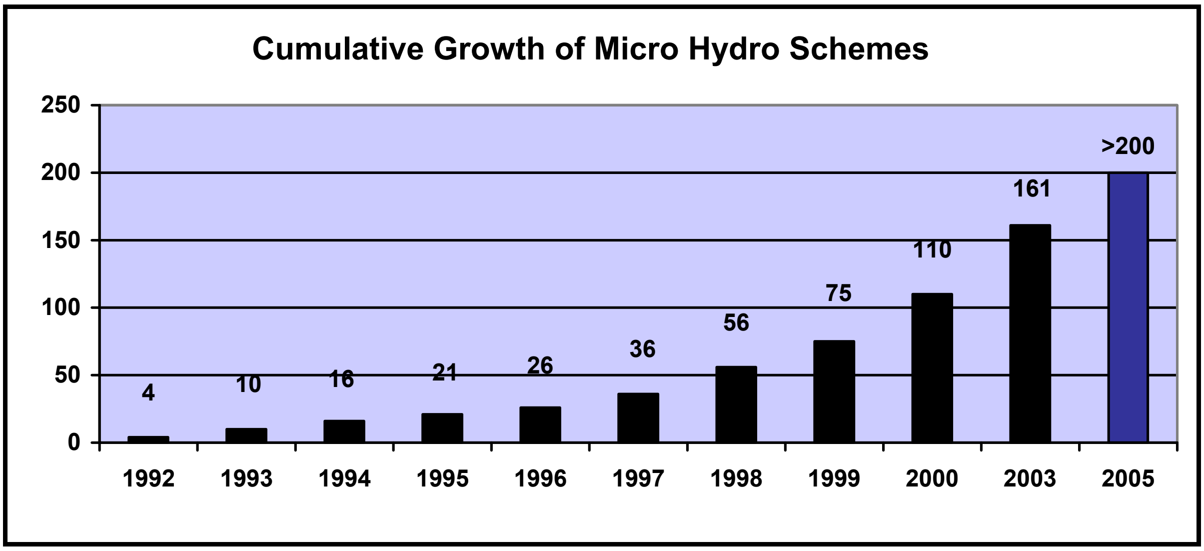

Figure 4: Cumulative Growth of Micro Hydro Schemes since 1992[32]

The number of more than 200 MHP schemes in the year 2005 is assumed by the author, as there is no data available for the year 2004 and 2005. This estimation is based on the addition of the total number of MHP projects implemented in the course of the ESD project. In the year 2003, this is the year of the most actual data, these projects were mostly still in construction.

If Sri Lanka's electricity demand continues with the prevailing expansion factor of 7% annually and Sri Lanka has still no solution for the energy question the energy crisis is not to be solved. For this reason the government authorities should take the implementation of small and micro hydro power schemes in the form of decentralized energy option into serious consideration.

[32] Source: ITDG Asia & estimation for the year 2005 by author

On the one hand MHP has advantages like significant improvements in education, sanitation, healthcare and the overall standard of living. These benefits are achieved both directly – as in the supply of light - and indirectly - as the time and money that people save is redirected into other projects. On the other hand by reducing the need to cut down trees for firewood and increasing farming efficiency, MHP has additionally a positive effect on the local environment.

According to ITDG the cost for a typical micro-hydro system varies depending on the project. As a guide every installed kW cost around US$1,200. A six kW scheme, which is enough to drive an electric mill and provide light for a community of about 500 people, would cost approximately US$7,200. ITDGs experiences show that community capital in form of "sweat equity" and cash, financial credit and improved income makes these schemes economically viable and sustainable.[33]

The Micro hydro study conducted also by Sunith Fernando (ITDG Sri Lanka), offers important data on about how many off-grid micro hydro potentials are available in Sri Lanka and how many of them are worthwhile developing them, considering both the technical feasibility and also the need for energy in non-electrified remote areas.[34]

The largest number of sites (227) is located in Ratnapura making 26% of the total 853 surveyed sites. The next larger percentages are indicated by the districts Badulla (19%), Kegalle (16%) and Kandy with 15%. This is shown in the figure below.

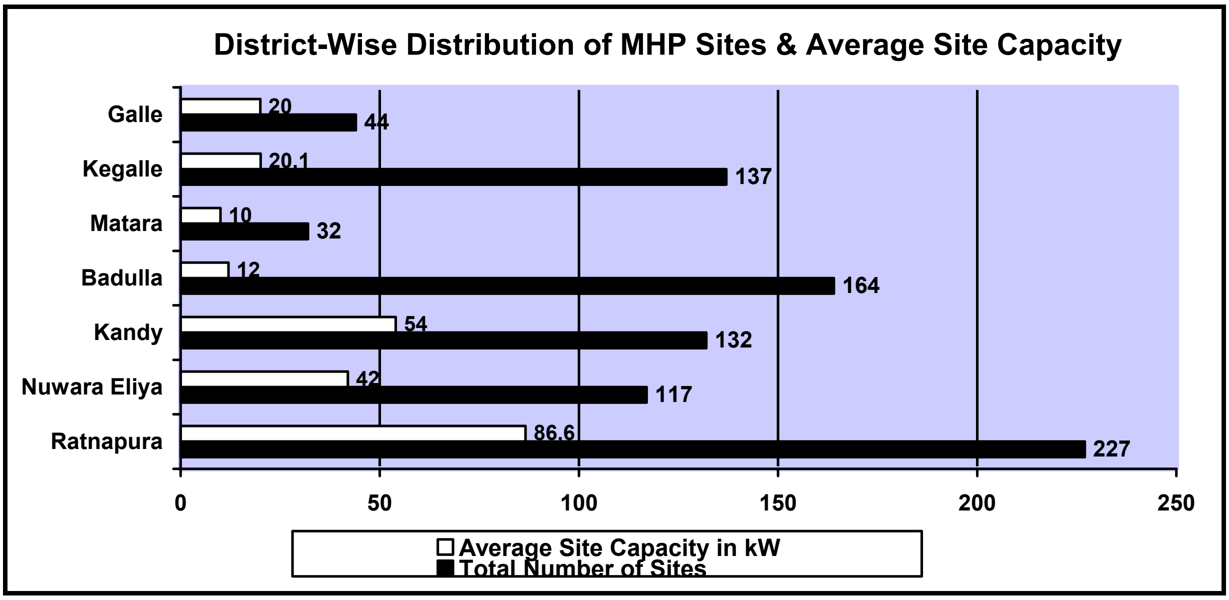

Figure 5: District-wise Distribution of MHP Sites & Average Site Capacity

The above figure shows comparatively high potential for micro hydro development in Ratnapura, Kandy, Kegalle, Nuwara Eliya and Badulla districts. Furthermore, Ratnapura,

[33] The information in this chapter 6.6.5 has its source *Assessment of Off-Grid Micro Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 2000 as long as no other source is given.

[34] Please note that the study is mainly based on the data collected from the desk study, which has been conducted by using topographic maps of the Survey Department. Furthermore, the districts of Matale, Kalutara and Moneragala are not surveyed in this study.

Kandy and Nuwara Eliya show high average site capacities while their electrification rate is also high, being 45-70% compared with only 10-20% in other districts.

The Micro hydro study revealed in the year 2000 that the aggregated potential of 37 MW power could be generated by developing micro hydro schemes in the explored locations. *"The affordability of possessing a micro hydropower project was discussed with some of the respondents during the sample verification. It was revealed that the communities possess the necessary financial capacity to afford the expenses involved in maintaining the micro hydropower generating plant in most cases. The enthusiasm and the consensus of the villages were observed although there were a few reservations due to the inherent limitations of micro hydropower."*[35]

This is together with the main overall conclusion of the Micro hydro study illustrated in the table below.

District	Desk Study Results			From the 10% sample visit		
	Total No. of sites identified from desk study	Aggregated power (kW) potential based on desk study	Average site capacity (kW)	Already electrified	Probable No. of sites without electricity and also technically viable	Probable aggregated power potential (kW)
Galle	44	875	20	20%	35	700
Matara	32	324	10	25%	16	162
Badulla	164	1,964	12	39%	91	1,090
Nuwara Eliya	117	4,936	42	70%	34	1,435
Kegalle	137	2,750	20.1	33%	92	1,843
Kandy	132	7,157	54	61%	51	2,765
Ratnapura	227	18,529	86.6	45%	125	10,191
Total	853	36,535	-	-	**444**	**18,186**

Table 9: Main outcome of the Micro hydro study conducted by ITDG in 2000

Additionally, there is more actual data about MHP potentials in Sri Lanka. According to *GATS and the threat to community electricity in Sri Lanka, ITDG, May 2004,* the total MHP potentials of the island are **41,490 kW in 1,023 sites**. The outcome of the earlier MHP study is in this 41.5 MW included.

"The results show an estimated meteorological potential of 41,490kW in 1,023 sites in 10 districts of the Uva, Central, Sabaragamuwa and Southern provinces. The past experience shows that this capacity is sufficient to meet the basic power requirements for nearly 190,000 households (on the basis of 200 W per household)."[36]

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[35] Quotation from ibid. p. 3.

[36] Quotation from *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

1.5 Conclusions

It has been estimated that there are 200 MW of small water power sites up to a capacity of 5 MW and a further 250-300 MW sites between 5 MW and 25 MW. This total potential of around 500 MW is over 25% of the island's installed grid capacity as at 2003. And there are even more resources which are not recorded up to date, as the most actual literature for small hydropower found is from the year 2000. Sri Lanka's tremendous irrigation system, located mainly on the islands dry zone, offers surely more small hydropower low head sites as it was surveyed so far (8 MW).

Besides reactivating the numerous existing retired small hydro stations in the plantation area, it would be advantageous to construct many new small or micro hydropower plants.

The expansion of small-scale hydropower in Sri Lanka for the coming 10 years is expected to be between 200 MW and 300 MW.

If Sri Lanka's electricity demand continues with the prevailing expansion factor of 7% annually and Sri Lanka has still no solution for the energy question the energy crisis will not be solved.

In future, the use of hydropower, especially for electrifying remote communities must remain the main support for the country's electricity supply. It has so many advantages such as cost-effectively, sustainability, reliability, environmental compatibility, independency from overseas and much more. Therefore, Sri Lanka should ensure hydropower, one of her most reliable natural resources play an increased important role in the nation's future electrification plans, especially in rural communities. Small-scale hydropower has a future, not only in Sri Lanka.

1.5.1 Proposals Made by Author

- The long term goal is the systematic development of small-scale hydro as a supplementary source of energy to meet partly Sri Lanka's national electricity demand, especially in remote communities and additionally
- To ensure the maximum amount of renewable energy availability needed for economic activities.
- The immediate objective is to provide private power developers with ready access to the basic information on small hydro sites on the island, best also in the internet.
- Old estate micro and small hydropower installation which fell into disuse should be reactivated as soon as possible and new ones should be developed. The existing new estate sites in the range of off-grid rural areas should be new built without overloading the existing manufacturing capacities.
- Technology transfer (low head turbines up to 30 m) efforts between Sri Lanka and European enterprises should be made if possible. But in India, Nepal and China the situation has both similar circumstances to Sri Lanka and the needed technology.
- If micro hydropower is not feasible in an area, solar energy, wind energy or other forms like biomass should be considered.
- Private-Public Partnerships are essential to further develop the area so they become independent of donor aid programmes. The Uva province solar PV project is a good example of private-public partnerships.

1.5.2 The Lessons Learned in 14 Years of Practice

- The MHP industry is facing a particularly difficult paradox. The main demand from consumers in Sri Lanka is for electric lighting, but most of the financially viable installations provide mechanical power to productive enterprises.
- It may well be that micro hydro should be promoted for its role in securing livelihoods, or developing small enterprises, rather than as an “energy programme”.
- Regulations should be set so that: independent power producers can supply power to the grid at ‘realistic’ prices; and connection standards are appropriate for the power to be sold. Rules should be transparent and stable.
- Costs are highly site and country specific, are controllable with good management, proper sizing and suitable standards.
- Quality and safety standards should be enforced to prevent the users being exploited by shoddy equipment and installations.
- While government finance tends to favour large scale energy investments (in say large hydropower or fossil fuels), micro hydro has the opportunity of utilising local capital (even the creation of capital through direct labour to build civil works) and it is part of the new trend towards “distributed” power with much reduced costs of transmission.
- Financially self-sustaining projects have cash generating (usually day time) end-uses to produce cash flow and increase the use of the plant (load factor). Lighting-only systems will have the greatest difficulty in achieving financial sustainability.
- Subsidies are likely to be necessary if micro hydro schemes are to substantially improve the access of poor people to electricity.
- Selecting and acquiring micro hydro technology that is appropriate to the location and task remains a necessary condition for success (wrongly sized plant and inappropriate standards remain a constant threat).
- It is easier to make a profitable micro hydro plant socially beneficial than to make a socially beneficial plant profitable
- Regulations should be set so that: independent power producers can supply power to the grid at ‘realistic’ prices; and connection standards are appropriate for the power to be sold. Rules should be transparent and stable.
- Best practice suggests that the expansion of micro hydro will continue to need both “soft funds” and funds at commercial rates, particularly if micro hydro is to meet the needs of people with low money incomes.
- Funding will be needed to cover capital costs, technical assistance and social/organisational “intermediation”.

Table 10: Lessons Learned in 14 years of SHP practice, source: mainly ITDG[37]

[37] Adapted from *Best practices for sustainable development of micro hydro power in developing countries*, ITDG 2000.

Although small-scale hydro power has been promoted by various policy initiatives in the past decades the use and development of this renewable energy source was not widely spread. The interventions and other supporting activities initiated mainly by the ITDG in the last two decades are explained below:

- Provision of technical assistance in the early phase of rehabilitating abandoned micro hydro plants in the Plantation Sector
- Developing the local engineering capabilities in design, operation and maintenance of small hydro plants
- Provision of O & M training for operators and mechanics engaged in small hydro plants
- Technical assistance towards manufacture of Pelton turbines
- Technical assistance towards the manufacture of Electronic Load Controllers (ELC) and Induction Generator Controllers (IGC)
- Demonstration and promotion of decentralised, community managed, micro hydro schemes to provide basic electricity needs of people in remote villages lacking access to the national grid.
- Inclusion of village hydro in the National Energy Policy.

The Government has so far undertaken two projects with the assistance of the World Bank. One is titled The Energy Services Delivery Project (1997-2002) and the other Renewable Energy for Rural Economic Development (RERED). The ESD Project was instrumental in the installation of 18,600 solar home systems (totally 875 kW), 56 off-grid Village hydro projects (aggregate capacity of 574 kW) benefiting 2,900 homes and 15 grid-connected small hydro projects generating a total of 31 MW. The RERED Project actively supports Sri Lanka's vision of expanding rural electricity access to at least 75% by 2007. Up to date there are 21 grid-connected small hydro projects with an aggregate potential of 58 MW and 68 off-grid village hydro projects (748 KW) approved and in development.

Nowadays, especially because of the ESD and RERED project, MHP, to electrify off grid areas, is getting more and more attractive. In November 2003 there were 161 off-grid micro hydro power (MHP) stations with a total capacity of 1,622 kW in operation providing basic electricity needs of 3,687 households. Even if the power outcome is relatively low this is seen very successful due to remarkable achievements in terms of the number of units and households electrified. It is estimated that there are still about 1.023 micro hydro power off-grid locations having an aggregate capacity of about 41.5 MW. This could serve 190.000 households in remote areas to decrease the total number of about 2 million un-electrified households nationwide.

More than ten years of off-grid energy market development has created much awareness of the role of technologies such as Solar PV and MHP. However, there are yet some general barriers at the government level.

- Off-grid energy is not incorporated into mainstream energy policy, which only focuses on large scale generation and grid extension. Politicians yet offer grid extension for votes.
- The Electricity Act allows only the CEB to generate and sell electricity to consumers. As such, the micro hydro projects are not legal. They operate as independent cooperatives and charge a membership fee from consumers (ECS).
- Funding will be a problem once the World Bank project RERED ends.

Attention must be paid to proper structure of power-purchase tariffs so that renewable energy receives credit for the value it creates, in terms of both energy and capacity. So far, there are no cases, in Sri Lanka, where power production is linked with providing rewards to service providers. However, the existing energy conservation fund could act as an intermediary facilitating some sort of transfer between environmental service providers and beneficiaries.

There is a lack to be filled as the political goal is to reach 100% electrification rate but the grid based rural electrification or diesel generators in remote areas is very costly. Off-grid electrification technologies such as micro hydro, solar and wind (when available) could fill this gap wherever they emerge as cost-effective options. Especially, it is necessary to investigate the viability of these technologies in situations where the load is prevailingly domestic lightning and also when the consumption per household is relatively low.

1.5.3 Recommendations

ITDG Sri Lanka drew up a plan to tackle the prevailing issues in order to guarantee that small hydro power is ready to take up the challenge of electrifying the remote segments having no or little hope of grid electricity. The actions and strategies proposed by ITDG Sri Lanka are as follows:

- **Setting up standards and regulatory mechanisms to maintain quality and standards of equipment and services**
- **Building capacities at supplier/manufacturer level through training and formation of an association among suppliers**
- **Facilitation of technology development and transfer**
- **Networking between key partners**
- **Legal status of off-grid community based micro hydro systems**[38]

[38] Adapted from *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* J. Gunasekera, Technology Programme Leader ITDG-South Asia, Nov. 2003.

The next important steps for the Electricity Consumers' Society's (ECS):[39]

- reviewing its efforts to produce and share energy, and get the same replicated
- developing grid-connected village hydro schemes, managed and maintained by the ECS as an income-generating project for other village development work
- continuously monitoring of the project. Essentially, this is an effort to share its capabilities with others, while consolidating the current achievements.

Furthermore, the willingness of the CEB to purchase power and stability of the purchase tariffs should be guaranteed. CEB should not place bureaucratic obstacles in the path of SHP developers. These cause only developers leaving their development plans in frustration.

Interviews with experts in Sri Lanka about renewable energies and SHP have resulted:

According to Dr. Nishantha there is lack in new developments in the turbine manufacturing technology in order to use new type of turbines. Remaining components of a hydropower scheme like turbine housings, generators, controls or switchgear are already manufactured successfully in Sri Lanka or imported from India, Nepal or China.[40]

Technology transfer is required especially in the low head hydropower sector in order to harness numerous low head sites of the islands tremendous irrigation system.[41] Mr Harsha from the Energy Conservation Fund emphasized the need low head turbines like e.g. Cross Flow turbines below 30 m in order to feed the national electricity grid. Designs between 30 m and 100 m are already manufactured locally.[42]

In Conclusion

Despite all this, it is still the kerosene lamps that provide light for over a half of the 3 million students in Sri Lanka; it is still the imported mineral oil that provides fuel for over a half of Sri Lanka's population. The time has now come to put a stop to that dependency through use of locally available and renewable energy sources. A new era of empowerment has begun, which will be fully realized only when this "powerless" 35% of the nation has gained access to an environmentally friendly and efficient power source, maybe through the installation of many more village hydro schemes.[43]

Finally, to gain a comprehensive view of the nation's actual investment situation, the following quote from the DFCC bank seems to be appropriate.

"Sri Lanka, located at the crossroads of the East and West, boasts one of the most investment-friendly business climates in South Asia. The country's open economy, highly literate workforce, and transparent investment laws provide the essential ingredients for a healthy investment environment. Combined with the beauty of its natural landscapes, its alluring beaches and rich cultural heritage, Sri Lanka is without a doubt an ideal destination for any investor."[44]

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[39] *Micro Hydro in Sri Lanka*, Lahiru Perera, Tilak Karunaratne, TCDC Training Workshop on SHP, 2002

[40] Interview with Dr. Nishantha Nanayakkara, Head of the Small Power Developers Association in Sri Lanka, 11.2004.

[41] According to Mendis it is estimated that about 30000 water storage reservoirs have been built in the dry zone, in an area of about 15000 square miles.

[42] Mr Harsha, Energy Conservation Fund, Sri Lanka, 25.11.2004.

[43] Compare ibid.

[44] Quotation from *DFCC Bank Sri Lanka*, online under: http://www.dfccbank.com/country.htm [2005.01.12].

2 Introduction and Target

Sri Lanka, a tropical island situated in the Indian Ocean to south-east of India covers an area about 65,610 square kilometres and is approximately 430 km long and 225 km wide. There is approximately 10% (6,510 sq km) of the island irrigated land. The estimated population as of 2004 was about 19.9 million with the highest population density in the south-west sector.[45]

2.1 Background

"Despite of consecutive occupancy by Portuguese, Dutch and British people, Sri Lanka developed a strong identity based on a secular cultural heritage. Even if the country is still belonging to the developing countries, and if two decades of civil war between Singhalese and Tamil ethnic groups resulted in a difficult situation, Sri Lanka is proud of being one of the Southeast Asian countries with the highest life expectation and the less illiteracy rate. Political and economical situation suffered a lot under the civil war, but the last efforts of Sweden to make both parts in the conflict sign a peace treaty resulted in relative stable circumstances – and allow the launching of new projects for improving quality of life."[46]

The central highlands are in the southern half of the island and compromise a series of plateaux and peaks, the highest of which is 2,524 metres. The shores are mostly sandy beaches.

The country has a variety of climates dependent upon the monsoons and altitude. There is a division into three districts areas, the wet zone, i.e. the south-west sector, the dry zone of the north and east, and the up-country or south-central highlands. In the dry zone, the annual rainfall varies from 1,015 mm to about 5 mm, where other parts experience intermittent and heavy rains.

Sri Lanka has been blessed with a great wealth of natural resources, rich soil, tropical climate and many rivers. Slopes of deep valleys terraced into rice paddy, mountain sides covered with tea, scenic rubber plantations, fragrant spice, tropical fruit and coconut estates all contribute to the lush agrarian life of the country on which the economy is primarily based. A remarkable diversity of land formation, vegetation and climate occurs here, especially considering the relatively small size of the island. Apart from a natural fertility of the soil and favourable climate, Sri Lanka is well endowed with minerals and graphite, phosphate, limestone and precious and semi-precious stones.

Rural ecology thrives in the midst of a developing agricultural society. Most village folk are involved in cultivation as a livelihood. Sri Lanka continues to be an island of villages in rural landscape with only 30% living in urban areas. Furthermore, at least 25% of the inhabitants do still not have access to electricity. They still use kerosene lamps for lighting or car batteries (which they have to recharge sometimes some several kilometres away) for minor electrical appliances such as television or radio.

[45] Source: *CIA World Fact Book*, online under: http://www.cia.gov/cia/publications/factbook/geos/ce.html [2004.11.15].

[46] Quotation from *Solar thermal systems*, Diploma Thesis by Roland Zwickl, TUM, UoM, 2004, p. 7.

2.2 Objective of this Report

The objective of this report is to provide a Comprehensive and Authentic Reference Document by gathering Sri Lanka's total small-scale hydropower (up to 25 MW) resource development potentials. Micro hydropower (up to 100 kW) for rural electrification plays herby the central role. It is also aimed to report the present status of the utilization of small hydropower resources and to make proposals for the future small hydropower development in Sri Lanka.

2.3 Motivation

Two of the biggest challenges facing the world in the 21st century are eradicating poverty and reducing global warming. Therefore, various international initiatives are promoting the use of renewable energies like small hydro-, wind-, solar power or biomass.

2.3.1 Aim of Renewable Energy Initiatives

Renewable energies and energy efficiency were recognised by the *International Conference on Renewable Energies* in Bonn (2004) as holding the key to providing safe and affordable energy services to those that have none, supplying future global energy needs, and decreasing the threat of disaster from climate change. Five major objectives of recent renewable energy initiatives are listed below:

- **To support sustainable development in the developing world**
- **To reduce the environmental impact of energy production and consumption**
- **To enhance energy security**
- **Reduction of inequality and universal access to adequate energy services**
- **Creation of jobs and sustainable livelihoods**

Table 11: Major Objectives of Recent Renewable Energy Initiatives[47]

Renewable energies, often decentralised and small scale, coupled with an end to policies that promote wasteful energy consumption, are significant to achieve these aims.

2.3.2 Chances for Poor Countries

World-wide, water delivers more energy than nuclear power plants. And there are even much more unused potentials. Asia, Africa and Latin America use only one fraction of the hydraulic power reserves of their countries. International environmentalism organizations fight in the poor regions for a higher standard of living. However, they warn against attempting this with the help of fossil energy. Only regenerative energy forms could mean a sustainable development. Water power, especially small hydropower can develop further its positive energy, only if ecosystems are spared and rivers and seas, animals and plants are taken into account.

[47] Source: *Twelve Reasons to Exclude Large Hydro from Renewables Initiatives*, International Rivers Network (IRN), November 2003, p.2.

2.3.3 Advantages Small Hydropower

Water power is most associated with vast dam-building projects that consume huge amounts of capital and generate hundreds, or even thousands, of megawatts. In some cases massive and controversial large-scale plants were constructed, especially in Africa (dams such as Kariba, Aswan, Volta, Cabora Bassa) flooding hundreds of square kilometres to store cubic kilometres of water. Therefore today, in an era of greater sensitivity to the environment, this kind of projects have given every kind of hydropower a bad name. This is due to the huge artificial lakes which have had considerable negative environmental impact in terms of displaced populations, loss of land and even considerable greenhouse gas production because of rotting vegetation in the lakes. Such lakes can gradually silt up, finally to become malarial marshes with greatly reduced capacity for water storage.[48]

At the other end of the scale, however, is small hydropower (SHP up to 10 MW) – used extensively in the past for application of shaft power or to generate small quantities of power for Sri Lanka's isolated communities, industrial units such as mills, mines and workshops. Lately however, due to the low cost of fossil fuels, Sri Lanka's national grid extension and the economics of scale of large hydro energy schemes and the massive quantities of energy required by the utilities, small and micro hydro schemes have been partially abandoned. Even for isolated villages where fuel supply is expensive and difficult, planers do prefer to install diesel units or grid connection instead of small-scale hydropower. The main argument is "The large investment costs" required by small hydro schemes. By using appropriate implementation methods and standards SHP can be a competitive option to provide energy to isolated rural areas and industries. It also offers additional advantages too because it is friendly for the environment and has no greenhouse gas emissions and its fuel is free of cost.

This technology is not new. Earlier this century small turbine installations were used all over the world. An upsurge of interest in recent decades has led to programmes in a number of countries to establish many new small-scale waterpower plants, particularly in isolated areas where they represent the cheapest form of energy. Viability of using off-grid SHP technology for rural electrification has gained popularity in Sri Lanka since the first demonstration in 1991 by the Intermediate Technology Development Group (ITDG). By that time its application is steadily growing. Advances in fully automated hydropower installations and reductions in manufacturing costs have made small hydropower increasingly attractive.

Not only in the industrial countries like e.g. Swiss, Norway or Canada small-scale hydropower is getting more and more common. In China, for example, the construction of small hydropower stations has been very meaningful in the past 25 years. Besides the development of large resources, much emphasis was given to small-scale developments resulting in an estimated 100,000 stations around the vast countryside with installed capacity approaching 10,000 MW. In other countries, such as Malaysia, Thailand and Peru national programmes for the introduction of MHP for small communities have been established. In India, it is estimated that there is a potential of 10,000 MW small-scale hydropower projects.[49]

[48] Compare *small hydro deserves to have its development accelerated in most parts of the world,* Peter Fraenkel, Renewable Energy World, March 1999.

[49] See *Small Hydro Power Plants*, E. Bedi, CANCEE, H. Falk, "Energy Saving Now", online under: http://energy.saving.nu/hydroenergy/small.shtml, [2004.10.05]

Basic water turbine technology had been developed to a high degree by 1930 and there have been few innovations since then. During the last three decades appropriate technologies to reduce implementation costs have been developed by researchers and institutions in order to compete with other available options like grid extension and diesel generation.

Small Hydropower is Important for Sri Lanka

Small hydropower is a very important source of energy, especially in Sri Lanka, the reasons being:

Advantages of Hydropower in General
• Hydropower is one of the cheapest renewable energy sources. Hydropower energy is mainly in competition with thermal sources of energy. • Thanks to the good actual forecasting tools for hydrology resources, long-term planning for hydro energy is possible and long-term assurance of viable payments for supply to the network and stable costs can be guarantee, compared to fluctuating prices of the fossil energy. • Impact on environment is minimal if sufficient precautions are taken. • Because of the fast start or stop of hydraulic turbines and the large operating range of these machines, hydro energy permit easy control of load on the grid. Comparable flexibility is only possible with gas turbines. • The possibility of energy storage in a reservoir permit to manage the production in the best economical interests, to store energy during off-peak hours and to release it during peak hours (these property is particularly interesting in complement of other sources of energy like nuclear power or wind and solar energy,…) • Hydraulic power permits very secure regulation techniques, that permits to guaranty high quality of current in comparison of others sources like wind energy where rapid unpredictable fluctuations are present Hydroelectric projects can also provide other vitally important benefits. These may include some combination of flood control, irrigation, recreation and water supply. • Hydro plants are well adapted to decentralized energy production in remote area and easily adjustable to local energy demand.[50]
Advantages of Small Hydropower especially in Sri Lanka
• There are plenty of rivers and streams in the hills. • The national power grid extends to only a limited area. • Low investment capability of the people • Scattered settlements. • Low purchasing power of the people. • Low electricity consumption of the people.[51]

Table 12: Advantages of Hydropower in General & Small Hydropower

[50] Adapted from *Objectives for Small Hydro Technology*, Institut National Polytechnique de Grenoble, 1999.

[51] Adapted from *Financial Guidelines for Micro-Hydro Projects*, ITDG Nepal publications, 1997.

What can Micro Hydropower do?

Micro hydropower plants in Nepal are being used for the following purposes:

• **Charging batteries**	• **Operating wooden utensil making machinery**
• **Operating irrigation pumps**	• **Lighting and using other electrical appliances (Radio, TV)**
• **Hulling rice**	• **Operating weaving looms**
• **Expelling oil**	• **Running cottage industries to produce Bakery products, Biscuits etc.**
• **Grinding grain**	• **Operating cotton carding machines**
• **Using heaters, rice cookers**	
• **Operating saw and paper mills**	

Table 13: Purposes for Micro Hydropower Plants in Nepal[52]

2.4 Organisation of the Report

This report is divided into seven chapters. The first chapter presents an abridged version for decision maker. The second chapter deals with the definition of small-scale hydropower in Sri Lanka's context and the justification of this report. Chapter three explains the actual energy situation in Sri Lanka. An overview of the physical feature and climate is given in chapter four. After describing the basics about small hydropower in chapter five, the core of the report starts with chapter six. It identifies the existing potentials for small hydropower and the costs to develop them.

The final chapter of proposals is the substance of this report. It provides suggestions on how to act in future in order to harness the surveyed potential sites.

At the end annexes are available containing information on general recommendations for the Sri Lankan power sector and tips and tricks for the habitants to save energy. Additionally, actual data about small hydropower sites developed under different supporting programs (ESD, RERED) is available.

This report has been made as simple as possible in order to make it easily understandable to ordinary hydropower entrepreneurs. A number of tables and illustrations have been given to make the theme easy to comprehend.

[52] Adapted from *Financial Guidelines for Micro-Hydro Projects*, ITDG Nepal publications, 1997, p.3.

2.5 Scope of Mission

Within the context of the collaboration between the University of Moratuwa (UoM), Sri Lanka and the Technical University of Munich (TUM), it is aimed to analyse the island's potential of renewable energies – solar, water, wind and biomass. The foreseeable potential of these energies is remarkably high in Sri Lanka because of the meteorological, geographical and topographical situation.

Everything started in March 2002, when a high ranked delegation of TUM went to India and Sri Lanka to sign contracts with IIT Delhi, IIT Bombay, IISc Bangalore and last but not least with the University of Moratuwa (UoM) known as the best technical university in Sri Lanka. In April 2002, Dr. Eng. Blumenberg, chief engineer and head of the Solar Research Centre, representing the Faculty of Mechanical Engineering, was authorized to travel a second time to UoM and to start the collaboration of both universities by a project on *Present Status of the Power Sector in Sri Lanka and Potentials of Renewable Energies in the Country*.

This project title corresponds with the wish of the Minister of Power and Energy, Hon. Karu Jayasuriya, whom Dr. Eng. Blumenberg met in his office and later in his residence. The Minister was highly interested in reducing conventional energies by means of renewable energies for the benefit of his country.

During the year 2003 the Memorandum of Understanding was discussed, agreed upon and signed by the two parties, Dr. Eng. Rahula Attalage (head of the Mechanical Engineering department) for the UoM as well as Dr. Eng. Blumenberg and Dr. Eng. Spinnler for the TUM.

Later, in October 2003 the first two students from Germany, Michael Schuster and Florian Jost, started their work on the *Present Status of the Power Sector* and *the Potentials for Wind Power in Sri Lanka.* Before finishing their work and leaving the country a second group of students arrived at the end of March 2004. Both Roland Zwickl and Julien Fortin have continued and expanded the project with the second stage containing evaluations on *Solar Thermal* as well as *Biomass Systems*.

The final part of the project started in October 2004 with the arrival of a third generation of diploma students, the author of this report Yasin Akgün, and Andreas Kruselburger. Their aim is the assessment of small hydropower and photovoltaic potentials.

The last diploma student Jorge Lopez, living since November 2004 in Sri Lanka, is finishing the *Potential Analysis* by the end of March 2005. Based on the successive work of the teams before, he will report the outcome of the whole assessment of renewable energy potentials on the island and make concrete recommendations which way Sri Lanka should go to answer their energy question in a sustainable way.

Yasin Akgün's mission commenced in Sri Lanka on 1 October 2004 and completed in Munich on 28th February 2005. He had to return earlier because of the Tsunami disaster on 26th of December 2004.

3 Energy Situation in Sri Lanka

Sri Lanka's total energy consumption in 2000 stood at about 4,906 kilotons of oil equivalent (ktoe) of biomass, 3,603 ktoe of petroleum and 767 ktoe of electricity comprising the following mix:

- Biomass (53%),
- Petroleum products (39%) and
- Hydroelectric resources (8%).

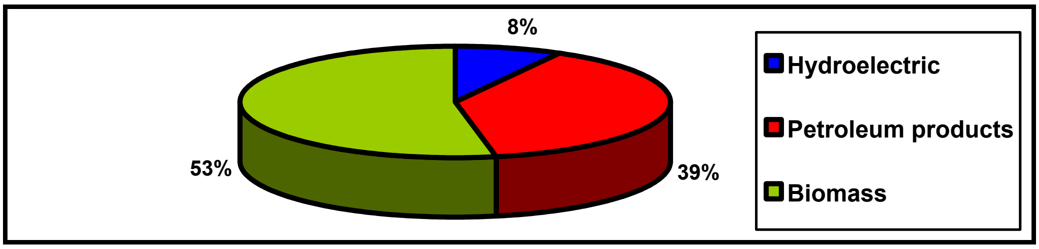

Figure 6: Gross Primary Energy Supply by Source (2000) [53]

Fuel wood still dominates the domestic sector consumption being the cheapest and most easily accessible source of energy. The annual consumption of fuel wood and agricultural residues makes an amount, to around ten million tonnes. While the bulk of fuel wood supply amounting to 85% of the total is consumed in the domestic sector at low efficiency in traditional fuel wood stoves, the rest is used in the industrial and commercial sectors. Energy efficient fuel wood stoves were developed and encouraged in order to popularise fuel wood conservation. According to a study on the energy need of rural households[54], 98% of rural homes use fuel wood for cooking, whilst one-third of these homes also use other kinds of biomass, like residues from rice mills and coconut shells. A Forestry Master Plan has been developed addressing the depletion of the forest cover and the supply of the industrial timber and domestic fuel wood needs.

Energy conservation programmes were successfully pursued in the past in several large energy consuming industries. The domestic share of petroleum product consumption reduced from 30% in 1972 to 12% in 1990. Domestic sales of petroleum products in 1998 amounted to around 2 million tonnes while the transport sector is responsible for almost two-thirds of petroleum product consumption. [55]

Sri Lanka's power sector is suffering from severe problems. There have been serious shortages of electricity in the past five years. This is on the one hand due to delays in completing investments in power stations and infrastructure to meet growth in demand and on the other hand due to irregular monsoon rainfall and bad administration by the Ceylon Electricity Board. E.g. they purchased plants which do not function properly. Emergency measures to increase the amount of available power, through, for example, the installation of diesel generators were carried out. They have reduced the shortages but this has also led to serious increases in electric prices.[56] Therefore electricity prices on the island are among the highest in South Asia, and power supplies remain unreliable and voltage fluctuations are significant. Despite the high prices the power sector is operating at a loss.

[53] Source: *Longterm Generation Expansion Plan, CEB,* 2003.

[54] *Energy Needs of Rural Households*, Atukorale, K, Energy Forum, Colombo, 1994.

[55] Compare *Renewable Energy in South Asia -Status and Prospects-*, World Energy Council, Nov. 2000.

[56] See *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

The total installed capacity of power plants in Sri Lanka is about 2,000 MW, 58% of which is hydro-based. The rest is fossil-fuel based using small steam turbines, gas turbines and diesel engines. Fossil fuel options, especially coal are expected to account for a large proportion of new generating capacity in Sri Lanka. About 41% of electricity consumption is accounted by households, 37% by industry and the rest by commercial consumers.[57]

The existing generation system in Sri Lanka is predominantly based on hydro power. It is the main indigenous source of primary commercial electrical energy with an estimated potential of about 2500 MW, of which more than half has already been exploited. 58% of the total existing CEB system capacity, which is about 2,000 MW (2004) is installed at 15 large hydro power stations with a total amount of 1,335 MW and an additional 56 MW small hydro installed capacity (2002). The rest of about 600 MW is fossil-fuel based systems. During the period 1972 to 1990 hydropower was producing up to 95% of the country's electricity. This amount decreased to 46% in 2000 and 40% in 2002. This is due to several droughts forcing the government to make Sri Lanka more independent from hydropower and more dependent from hydrocarbons.[58]

More than 45% of the islands total large hydropower potential is already harnessed. These are mainly multi task projects of controlling floods, supplying of irrigation water and generation of power. According to USAID *"all the Techno-economically feasible hydro-power potential has been identified and the balance available, has been identified as approximately 1,268 MW. Out of which 1,066 MW is the estimated potential that can be developed. The balance may not be viable to develop due to environmental and economic barriers."*[59]

Particulars	In MW	%
Estimated Total Hydropower Potential (USAID/SARI, 2002)	**2,423**	**100**
Developed Total (USAID/SARI, 2002)	**1,137**	**46**
Techno Economically feasible for Development (USAID/SARI, 2002)	**1,066**	**43**
Large Hydropower under Construction (USAID/SARI, 2002)	**70**	**1,6**
Committed for Future Hydropower Projects (USAID/SARI, 2002)	**150**	**6,1**
Expected (USAID/SARI, 2002) Total Hydropower Development by 2012	**1,663**	**68**
Expected (United Nations University, 2002[60]) Total Development for *Large Hydro* by 2022	**220**	**~9**
Expected (United Nations University, 2002) Total Development for *Small Hydro* by 2022	**200**	**~8**
Expected (Finance Minister Sri Lanka) Total Development for *Small Hydro* by 2008	**300**	**~12**

Table 14: Sri Lanka's Total Installed Large Hydropower Capacities & Remaining Potentials

[57] See *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

[58] Compare *Longterm Generation Expansion Plan,* CEB 2003.

[59] Quotation from *Regional Hydro-power Resources: Status of Development and Barriers*, For United States Agency for International Development (USAID) under South Asia Regional Initiative for Energy (SARI), prepared by Nextant SARI / Energy, 2002.

[60] *Role playing game approach to introduce complex water resources decision making process*, Srikantha Herath, United Nations University, 2002.

Additionally, there are actually about 100 MW of installed small hydropower capacity feeding electricity to the grid. More information about the actual situation and prevailing potentials in the small-scale hydropower sector is available in chapter 6.

Generation Type	Number	Total Installed Capacity
Small Hydropower	30-40	100 MW
Micro Hydropower	200-250	~2 MW

Table 15: No. & Installed Capacity of SMH & MHP Stations Estimated by Author (2005)

In comparison to 100 MW in Sri Lanka, Germany has about 1400 MW of installed SHP plants. In 1999, the total installed capacity of Germany's power system was about 115,000 MW[61] while that of Swiss was about 17,000 MW.[62]

Opinions about the future of water power development in Sri Lanka are different. According the United Nations University, the expansion of hydropower for the coming 20 years is expected to be around 220 MW in major development and 200 MW of small hydro, which does not yield firm power. Whilst United States Agency for International Development (USAID) and South Asia Regional Initiative for Energy (SARI) expects about 500 MW of new hydropower stations developed in the next seven years.

The Finance Minister of Sri Lanka Dr. Sarath Amunugama said in one speech in 2004, that the *"plan is to raise supply from SHP units of 10 MW to a total of 300 MW by 2008."*[63]

However, fact is that there are still enough both large and small hydro potentials which could be harnessed to meet the islands increasing energy demand. The objectives of the hydropower policy should try to achieve the following:

- **To utilize the existing small-scale water resources and to ensure the returns so that the private investors are encouraged.**
- **To ensure the maximum amount of renewable energy availability needed for economic activities.**

Table 16: Objectives of Sri Lanka's Hydropower Policy, source: Author

Up to very recent past private investors were allowed to develop the plants only up to 10 MW. Now the limit is taken up to 50 MW and Energy Supply Committee of Sri Lanka has invited world wide "Expression of Interest" to develop the water power plants.[64]

The present government is interested in seeking possibilities of private investment to develop the water power resources. *"The Electricity Act of Sri Lanka of 1959 with various amendments from time to time does not allow any private investor to handle Generation or Distribution of Power in Large or small scale. However it is considered that with the License*

[61] Compare *Fact sheet Germany*, online under: http://www.renewable-energy-policy.info/relec/germany/ [2004.12.07]

[62] See Schweizerische Elektrizitätsstatistik, 2000, Swiss Federal Office of Energy, Bern.

[63] Quotation from *Power Politics*, online under: http://www.lankabusinessonline.com [2005.02.14].

[64] The Paper notice appeared on the Ceylon Observer (Weekend Paper) on 21st of July 2002 announcing the uplift of the limit of the plant that can be developed by the investors.

obtained from the Ministry of Power and Energy this legislation is overruled. Further with the reforms planned to privatize the Electricity Authorities in Sri Lanka the Electricity ACT shall be amended or modified. Two Main Authorities of Power Trade in Sri Lanka are Ceylon Electricity Board and Lanka Electricity (Pvt.) Ltd. However CEB holds controlling shares of LECO. "[65]

3.1 The Ceylon Electricity Board (CEB)

The Ceylon Electricity Board (CEB) is the statutory body in Sri Lanka and is accountable for the transmission and most of the generation and distribution of electric power. It was established by the government of Sri Lanka in 1969. It currently operates 15 large hydro power plants, 3 thermal power plants and 1 wind power plant feeding the national grid operating at 220 kV and 132 kV. Furthermore it purchases electricity from private sector through 17 small hydro power plants and 3 thermal power plants. The national power generation system owned and operated by CEB had in 2001 an installed capacity of 1,618 MW while the total installed capacity of private plants (including small hydro and thermal) is 210 MW. That makes an overall total installed capacity of 1828 MW. The maximum demand recorded in 2002 was 1,421 MW. The per capita electricity consumption in the country in 1998 stood at 247 kWh.[66]

Sri Lanka since 1996 is looking at costly non-hydro sources of power. The reason is the long drought in 1996 in hydro reservoir areas which resulted in power cuts up to six hours a day. The inadequate owner forced the government- monopoly Ceylon Electricity Board to increase electricity generation, mainly through use of expensive thermal and gas resources. However, cost of electricity is a key element in attracting foreign investments into the island for its economic development. Furthermore, the use of imported fuel caused and is still causing electricity price increases and unfavourable environmental effects. This prevailing energy crisis in Sri Lanka is a manifestation of more deep-rooted problems in the governance and development policies.

The Ceylon Electricity Board is the monopoly power supplier in Sri Lanka. That signifies that no other entity is allowed to produce power for sale to a third party, although such entities are entitled to generate power for their own consumption. There is no independent power sector regulator. Since the early 1990s the private sector has been allowed to build, own and operate generation plants up to 10 MW, for sale to the CEB grid. While there is no restriction on the capacity of thermal plants that private sector developers may build under this regime, the highest capacity SHP plant that a developer is permitted to build has increased in 2002 from 10 MW up to 50 MW.[67]

Developers of large (over 10 MW) thermal power plants enter into individual power purchase agreements (PPAs) with the CEB that included capacity related payments based on the developer's capital cost and variable energy payments based on agreed expenses for maintenance costs and fuel costs based on the international price of fuel. Developers of SHP plants (and other types of renewable energy based power plants) up to capacities of 50 MW (in 2002 only 10 MW) sign a standard power purchase agreement (SPPA) valid for 15 years.

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65 Quotation from *Regional Hydro-power Resources: Status of Development and Barriers*, For USAID under SARI, prepared by Nextant SARI / Energy, 2002.

66 Compare *Longterm Generation Expansion Plan*, CEB 2003.

67 Adapted from *Regional Hydro-power Resources: Status of Development and Barriers*, For USAID under SARI, prepared by Nextant SARI / Energy, 2002.

No capacity related payments are made for the generation by such power plants and the price paid per kWh of energy is set each year by the CEB, actually between US$0.05 – 0.06 cents. It is equal to the CEBs expected annual short-run avoided cost per kWh not generated as a result of purchase of one kWh under the SPPAs. This result in small hydro and medium hydro plant operators receiving rates based on the running cost of the CEBs diesel generation plants which operate at the margin most times of the year.[68]

3.2 Background of Sri Lanka's Power System

In considering the small hydropower development in Sri Lanka, it is needed to understand the overall development of the electricity sector in Sri Lanka. Electricity supply system from thermal stations was initiated in Sri Lanka (then Ceylon) in 1895, by a private enterprise to serve the capital Colombo. The Pettah Power Station was erected in 1898 for this purpose. Thereafter, all major towns and suburbs received their electricity mainly from an assortment of diesel generators. Kandy had electricity supply from 1901 and Nuwara Eliya from 1912. However, in the absence of fossil fuels hydropower has always been looked upon as the only form of natural power available in Sri Lanka.[69]

3.2.1 Hydropower vs. Thermal Power

As a result of this the work for the Ceylon Hydro Electric Scheme was started in 1928. The first major hydro electricity scheme however was the Aberdeen/ Laxapana Scheme realized only in 1950. That was the beginning of taming of the entire Kelani Ganga and its tributaries (Kehelgamu Oya and Maskeli Oya) now "*accounting for 335 MW of installed power and contributing 1450 GWh (Million Units of Electricity) in an average hydrologic year.*"[70]

Laxapana was the countries first modern hydro power station. The five stations in this complex are not needed to serve for irrigation or water requirements, hence, they are primarily designed to meet the country's power needs. The development of the major hydropower resources under the increased Mahaweli project added six large hydro power stations[71] to the national grid with a total installed capacity of 660 MW, amounting 58% of the total hydropower capacity. Several other large hydro schemes installed last century have continued to expand the reach of irrigation systems. Huge tracts of agricultural land were fed with water, displacing nearly 100,000 people.

In 1940s major power development started and hydropower was expected to meet peak and base loads while thermal power was added to meet hydropower shortages during dry periods. In 1960-62 a thermal plant was commissioned at Kelanitissa of an installed capacity of 2 x 25 MW of oil fired steam generators. Because of the liberalization of the economy the electricity demand during the period 1978 – 1982 grew with an averaging 12% per annum. This crisis led to urgent purchases and installations of 6 x 20 MW gas turbines burning diesel oil in 1980 and 1982. The second major thrust in hydroelectric development was the

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[68] See *Grid Connected Small Hydro Power in Sri Lanka*, Dr. Romesh Dias Bandaranaike, International Conference On Accelerating Grid-Based Renewable Energy Power Generation for a Clean Environment, 2000.

[69] Compare *Evaluation of Hydropower Potential of Existing Irrigation Schemes in Sri Lanka*, Kariyawasam, UoM & Fernando, CEB, 1988, p. 9.

[70] Quotation from *Hydro Power Development in Sri Lanka and Hydro power Pricing Issues*, S. Fernando, T. Siyambalapitiya, PhD, T.A.K. Jayasekera, 2001.

[71] These are Ukawela, Bowatenna, Kotmale, Victoria, Randeningala and Rantambe.

launching of the Mahaweli river diversion at Polgolla to provide irrigation water to Mahaweli areas. In the accelerated Mahaweli development 665 MW of hydropower was installed capable of generating 2030 GWh of electricity in an average hydrological year, while providing irrigation requirements for a large size of land. For this reason power generation of its stations is controlled by downstream irrigation requirements, which are seasonal. Already approximately over 80% the resources on Mahaweli River and the Kelani River are nowadays developed. One of the resources of Walawe River has also been developed.

Most of Sri Lanka's large hydropower schemes are multi-purpose projects, making irrigation the priority. These large-scale hydropower projects were financed mainly through bilateral aid in the form of long-term loans at low rates of interest and a large component of donor country expertise and technology transfer.

Major hydroelectric plants contributed 3,915 GWh of energy in 1998 while independent power producers generated 6 GWh giving a total of 3,921 GWh (69% of total generation) of hydro based electricity. The balance was generated by thermal based power plants. In the following years this situation changed drastic. In 2002 major hydroelectric generation was only 2696 GWh contributing only 39% to the total generation of 6,946 GWh.

The only large-scale wind plant came into operation in 1999 at Hambantota having produced 5 GWh during 1999. In the same year household usage of biomass stood at 8.6 million tonnes, while industrial consumption was around 1.9 million tonnes.

The contribution of the three small hydro plants (Inginiyagala, Uda Walawe and Nilambe) to the national grid is small (20 MW) and is dependent on irrigation water releases from the respective reservoirs, whilst private small hydro plants connected to the system amount around 37 MW. Further 37 MW of private plants are under construction and Letter of Intents has been issued for another 100 MW. Further information about the potentials of small hydropower and its contribution to the national grid is extensively discussed in the chapter 6 of this report.

While in 1993, hydropower was yielding 95% of the country's electricity generation, this amount decreased to less than 40% in 2002. This is due to several droughts forcing the government to produce more energy through burning of hydrocarbons in form of petroleum, gas or diesel.

Therefore large-scale hydropower development slowed down. This is also due to increasing difficulties in obtaining finances for the development of major hydro resources, coupled with difficulties in obtaining environmental clearances for large hydro projects. There exists still another 1,000 MW of technically feasible hydropower potential though their environmental acceptance and their economic feasibility have to be established.

Nevertheless no large-scale method of power production can be entirely without environmental impact. In many cases large hydro schemes might be a lot less harmful in general than most other methods of energy generation. Information about the difficulties of large water power and the reasons why it should be excluded from renewable initiatives are explained in the following section.

3.2.2 Small Hydropower vs. Large Hydropower

Until today, most hydro power capacity of Sri Lanka consists of large and medium-hydropower plants of many MW each. However there is a growing interest in so-called "small hydropower" or SHP, defined internationally as any hydro installation rated at less than 10 MW. A sub-set of SHP is micro hydropower (MHP), which covers systems of less than 100 kW used successfully for rural electrification in Development countries.

In recent years the use of small scale decentralised generation sources like solar home systems or small hydropower to bring power to remote communities has successfully increased. The use of small-scale generating technology to bring electricity to isolated communities is not just of relevance to Sri Lanka. There are 1.6 billion people worldwide without access to electricity. This policy which can be followed by many developing countries has the potential to bring major welfare benefits to poor communities.

"Small hydro can, if responsibly implemented, be environmentally and socially low-impact and provide many of the benefits of new renewables, in particular providing power and related development benefits to dispersed rural communities. If badly implemented, however, without regard to community needs or its impacts on rivers and streams, small hydro can replicate many of the negative consequences of larger schemes. The cumulative impacts of multiple small hydro schemes on small watersheds are of particular concern. It is thus imperative that small hydro schemes be carefully evaluated on a case-by-case basis. The site-specific nature of hydro means that it has been difficult to reach international agreement on a size limit for small hydro. According to the International Association for Small Hydro, however, a limit of up to 10 MW capacities "is becoming generally accepted." The European Small Hydro Association and the International Energy Agency's Renewable Energy Working Party also define small hydro as less than 10 MW. It is therefore logical to use this upper limit of 10 MW in efforts to promote renewables. To ensure that small hydro projects have low impacts and meet community priorities it is imperative that all small hydro schemes are planned, built and operated in line with the recommendations of the World Bank/IUCN-sponsored World Commission on Dams."[72]

Hydropower is currently the world's largest alternative source of electricity, accounting for about 19% of the world's electricity. In the following figure a ranking of top hydroelectric generating countries are presented. The contribution of small hydropower (less than 10MW) worldwide (1990) is estimated to be 19.5GW compared with 700 GW (1994) of large hydropower.

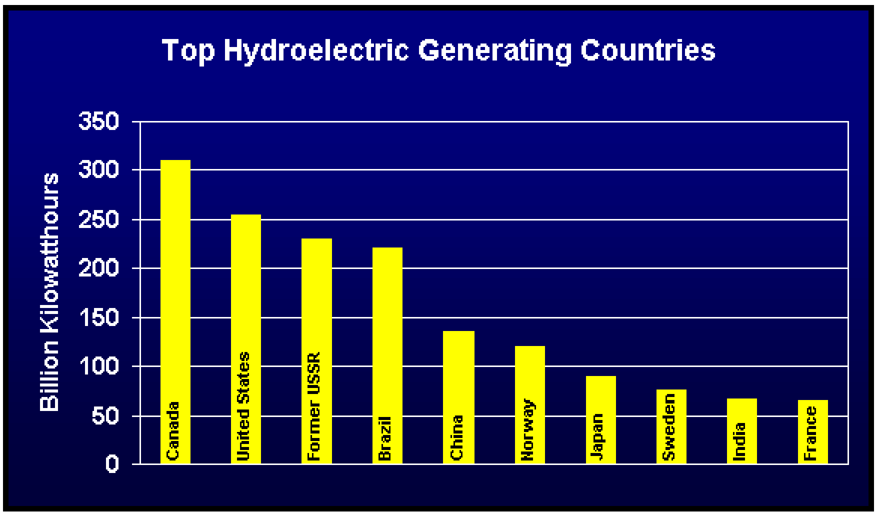

Figure 7: Top Hydroelectric Generating Countries (1998)[73]

[72] Quotation from *Twelve Reasons to Exclude Large Hydro from Renewables Initiatives*, International Rivers Network (IRN), November 2003, p.2.

[73] Source: http://www.groept.be/dam/Hydrocountries.htm [2005.02.13].

The world's gross theoretical hydro potential so far identified is approximately 40500 TWh/year. It has been estimated that 14320 TWh/year is technically feasible and about 8100 TWh/year is economically feasible at present for development. Therefore at present only 32% of the economically feasible potential has been developed, leaving some 1800 GW of installed capacity having an energy yield of 6400 TWh/year, which is available at present for development.[74]

Large hydro (plants over 10 MW)	**86 %**
Small hydro (plants less than 10 MW)	**8,3 %**
Wind and solar	**0,6 %**
Geothermal	**1,6 %**
Biomass	**3,5 %**

Table 17: Global Electricity Generation from Renewable Energies (1993)[75]

If large hydropower is count as a regenerative source for energy, the following figure about net generation by regenerative energies can be illustrated.

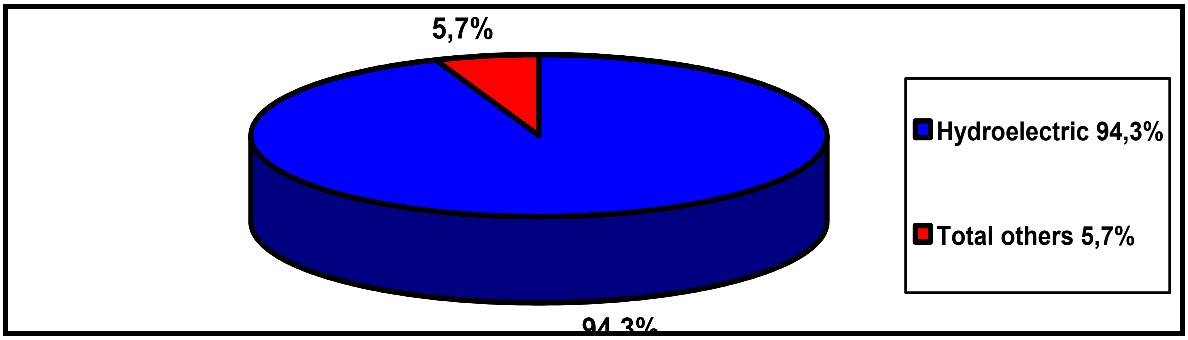

Figure 8: Net Generation by Renewable Energies (1993)

Every water plant is unique in its design, location and impacts. While there is no direct proportional relationship between the installed capacity of a water power system and its impacts, in general one can expect higher impacts as the size of the project increases. However, large hydro power is not consuming carbon or any kind of other resources. Large hydropower can develop its positive energy but only if ecosystems are spared and rivers and seas, animals and plants are taken into account. It should not be too large. 10 MW could be a good border as ecological acceptable. But this border depends very much from case to case. Whilst a 25 MW system could be developed without harming the environment another system with a capacity of 5 MW could have much more impact.

When considering the value of any single hydropower project, one must ask how that power will be replaced. Will it be replaced with other forms of renewable energy or conservation, or will the excess capacity of the existing fossil fuel mix make up the

[74] Source: *Small Hydro Power – State of the Art and Applications*, C. Dragu, T. Sels, R. Belmans, ESAT-ELEN, Energy Institute, Belgium, 2002.

[75] Ibid.

difference? Hydropower has environmental impacts, which are very different from those of fossil fuel power plants. More likely, it will fall to the regional power pool to make up the difference, with negative consequences to the islands air quality in the form of increased levels of CO_2. Nevertheless, large hydro power should be excluded from any initiatives to promote renewable energies, in particular from the Johannesburg Renewable Energy Coalition, the "Renewables 2004" conference in Bonn, and the Kyoto Protocol's carbon trading schemes. The reasons are listed on below:

- **A MAJOR EXPANSION OF LARGE HYDRO WILL HARM SUSTAINABLE DEVELOPMENT**
  1. **Large hydro does not have the poverty reduction benefits of decentralized renewable energies**
  2. **Including large hydro in renewable energies initiatives would crowd out funds for new renewable energies**
  3. **Promoters of large hydro regularly underestimate costs and exaggerate benefits**
  4. **Large hydro will increase vulnerability to climate change**
  5. **There is no technology transfer benefit from large hydro**

- **A MAJOR EXPANSION OF LARGE HYDRO WILL HARM PEOPLE AND ECOSYSTEMS**
  10. **Large hydro projects have major negative social and ecological impacts**
  11. **Efforts to mitigate the impacts of large hydro typically fail**
  12. **Most large hydro developers and financiers oppose measures to prevent the construction of destructive projects**
  13. **Large reservoirs can emit significant amounts of greenhouse gases**

- **A MAJOR EXPANSION OF LARGE HYDRO WILL HARM ENERGY SECURITY**
  10. **Large hydro is slow, lumpy, inflexible and getting more expensive**
  11. **Many countries are already over-dependent on hydropower**
  12. **Large hydro reservoirs are often rendered non-renewable by sedimentation**

Table 18: Twelve Reasons to Exclude Large Hydro Power from Renewables Initiatives[76]

From now on, large hydropower is not dealt anymore in this paper, which is concentrated on small hydro power up to 10 MW. Micro hydropower to electrify remote areas is playing hereby the major role.

[76] Source: *Twelve Reasons to Exclude Large Hydro from Renewables Initiatives*, (IRN), November 2003.

3.2.3 Rural Electrification and Off Grid Plan

Rural areas of Sri Lanka is often at a disadvantage in terms of access to all types of service like e.g. roads, health facilities, markets, information and clean water. Rural electrification is characterised by high investment costs, inadequate financial returns, low population densities, heavy power losses, high operational costs, and inaccessible locations. This has led to new approaches being tried, based on self-help and the private sector rather than traditional government-led solutions.

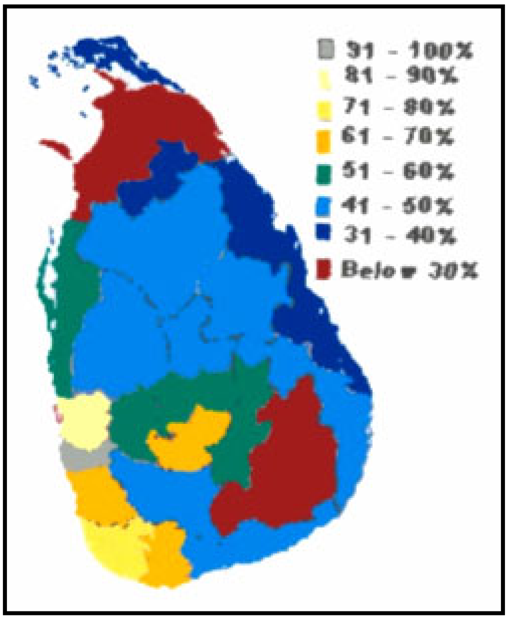

Figure 9: Level of Electrification, source: CEB[77]

Major rural electrification programmes undertaken by the CEB have resulted in the proportion of electrified households in the country increasing from about 10% in 1972 to around 65% in 2002 and when the planned electrification schemes are implemented it is expected that this will increase to 77% by year 2006. It is estimated that about 80% could reasonably be served by grid extension. Then in 1996, the Governments' aim was to extend the grid electricity availability to 75% of households by 1999, and to all by the year 2006.

The table below shows the constant growth of the electrification rate from about 7% in 1977 to 65% in 2002.

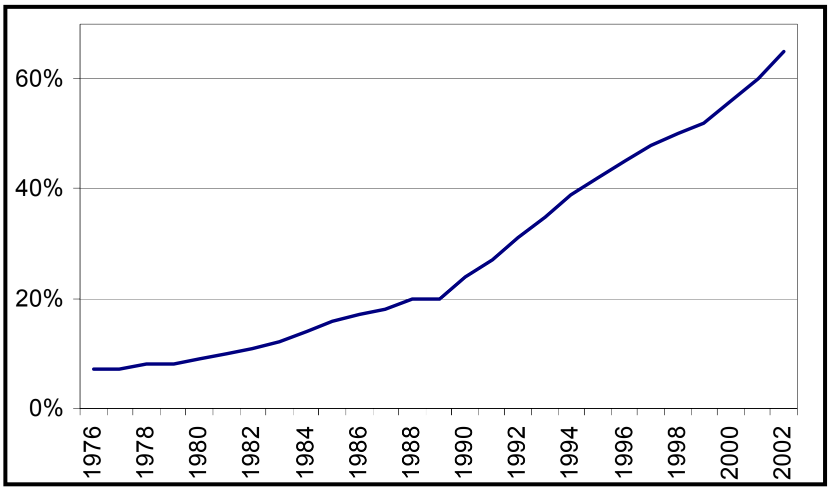

Figure 10: Electrification Rate during the last 25 Years[78]

[77] source: CEB Longterm Generation Expansion Plan, 2003.

Additionally, there is a great difference in the electrification rate among the urban, rural and estate sectors as illustrated in the following table. For example record more urbanised districts, such as Colombo and Gampaha electrification rates as high as 96% and 80% respectively, the rate in the socio-economically backward Monoragala district is only 15%.

	No. of Households	Electrified Households	Electrification Rate
Urban	880,000	836,000	95%
Rural	3,045,000	1,155,500	38%
Estate	275,000	27,500	10%

Table 19: Number & Distribution of Electrified Households in Sri Lanka[79]

Attempts have been made to promote photovoltaic (PV) for rural lighting, wind energy for lift irrigation, agricultural residues for industrial heating, biogas generators for domestic use and solar water heaters for industry, hotels and domestic use, but their contributions have still remained relatively small. CEB started popularising solar PV for rural domestic lighting in the early 1980s. Unlike off-grid micro-hydro and small wind systems it is presently the private sector, which is mainly involved in promoting and marketing domestic solar energy systems in Sri Lanka.

The private sector is developing a large number off grid connected as well as isolated small hydropower plants. However their total contribution still remains small in comparison with conventional large hydropower development.

Biomass based electricity generation is another technology option for rural off grid electricity generation. This method transforms fuel wood into electrical energy. There are three technologies tested and proven to transform dendro (fuel wood) energy into electrical energy world wide, but these have not yet been demonstrated in Sri Lanka in small scale operations. However, due to its potential as an indigenous source of energy and the possibilities in this fertile, green Sri Lanka, it has attracted widespread interest as a primary energy source for electricity generation. Additionally it withholds soil erosion, restores degraded land, creates local employment and has several other environmental benefits. Only the maintenance of a regular biomass supply could be an important task for effective implementation of commercial scale dendro plants. Presently two pilot dendro plants are in operation in Sri Lanka, one in Sapugaskanda (35 kW) by Lakdhanavi Ltd. and the other in Walapane (1 MW) by a private company.

[78] Source: *Solar thermal systems*, Diploma Thesis by Roland Zwickl, TUM, UoM, 2004.

[79] Adapted from *An Assessment of Off-Grid Micro Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 2000

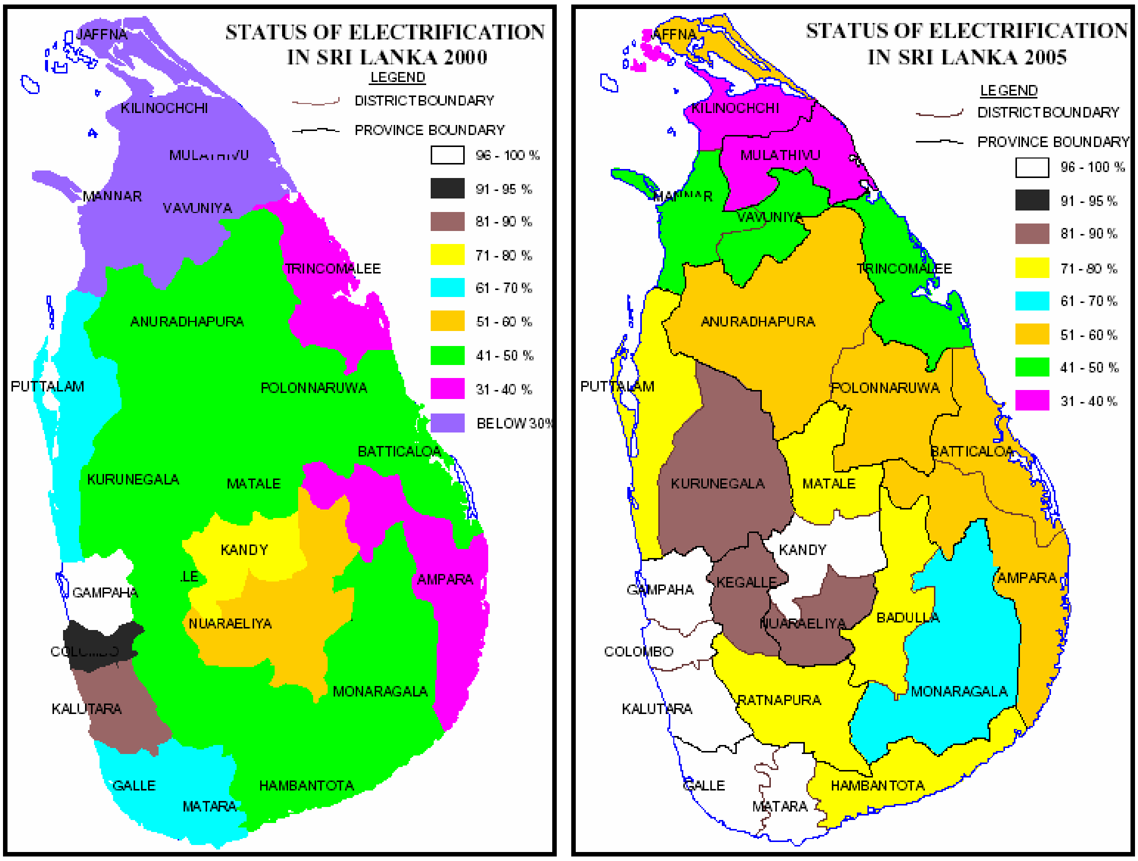

Figure 11: Level of Electrification, source: Energy Forum[80]

Opinions about the level of electrification on the island are differing. CEB and Energy Forum have different estimations. Nevertheless, there are at least 25%, mainly village people who need electricity for lighting, television or radio.

The strategy for rural electrification in Sri Lanka which follows the CEB is listed below:

- **Identify the electrified and non-electrified villages in rural areas**
- **Assess socio-economic situation of the villages**
- **Identify prospective developments of the village**
- **Define the selection criteria (based on a 12% IRR)**
- **Identify villages for grid extension based on a feasibility study**
- **Extend power lines to the village**
- **The CEB has projected that 80% of households will get the grid**

Table 20: CEBs Strategy for Rural Electrification of Sri Lanka[81]

[80] Adapted from *Rural Electrification in Sri Lanka*, Lalith Gunaratne, LGA Consultants (Pvt) Ltd and Energy Forum, 2002.

[81] Ibid.

Effects on Poverty

On the one hand rural electrification has advantages like significant improvements in education, sanitation, healthcare and the overall standard of living. These benefits are achieved both directly – as in the supply of light - and indirectly - as the time and money that people save is redirected into other projects. On the other hand by reducing the need to cut down trees for firewood and increasing farming efficiency, electrification has additionally a positive effect on the local environment.

According to the Energy Forum rural electrification has the effects on poverty as shown below:[82]

- **Improvement in quality of life**
- **Better health from improved indoor air quality**
- **Children can study longer hours resulting in better performance**
- **Access to information and entertainment (TV/Radio)**
- **Security**

Table 21: Effects of Rural Electrification on Poverty

These effects would bring about longer term benefits to the community leading to future economic growth. Whilst solar PV provides electricity for basic requirement only it could extend the hours for a village grocer or a sewing business. Micro hydropower has besides electrification also potential for community based income generation activities such operating a battery charging centre or rice mill. New technologies like as biomass based dendro power has potential for out growers to provide fuel wood to gasifier. [83]

3.2.4 Electricity Demand

Overall electricity demand grew from 823 GWh in 1972 to 6,946 GWh in 2002, representing an annual growth rate of about 7%. According to CEB this trend is expected to continue in the foreseeable future, if no nation wide efficiency improvement measures will be carried out. At this rate the country needs about 200 MW of power plants added to the system each year.

The following table shows the capita consumption of electricity in Sri Lanka in 1998. While in comparison to India and Pakistan this is relatively low, the electricity consumption per capita in Germany (2000) is with 3,841 kWh about 15 times more than in Sri Lanka.[84]

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[82] ibid.

[83] ibid.

[84] Compare *Globalis-Germany*, Global Virtual University, http://globalis.gvu.unu.edu [2005.01.17].

Country	Electricity Consumption (kWh per capita)	
	1980	1998
India	130	384
Pakistan	125	337
Sri Lanka	**96**	**244**
Bangladesh	16	81
Nepal	13	39

Table 22: Per Capita Electricity Consumption in SAARC Region[85]

3.3 Reliability of Sri Lanka's Electricity Network

The reliability of the nation's electric grid has become a growing concern for policymakers as the electric shortages are usual in Sri Lanka since the early 1990s. These are mainly the result of the inability of hydropower plants to meet system demand during times of heavy droughts, which come about every four to five years. For this reason do efforts to advance new clean and renewable energy sources often exclude hydropower in order to achieve independence of this renewable source of energy.[86]

The extent of such power shortages has increased in recent years due to growing electricity demand coupled with inadequate additions to thermal capacity. In particular, new generation capacity additions as proposed in the long-term generation expansion plan of the CEB have not been implemented in accordance with approved time schedules. The resulting power shortages have caused both planned and unplanned power interruptions that have seriously affected the quality of power supplied to consumers. This situation is common throughout South Asia, where the economies are significantly affected by poor power quality.

As we look for ways to shore up Sri Lanka's electricity grid and prevent future power outages, hydro power's value in maintaining system reliability must be fully considered. A reliable electricity grid is unquestionably the foundation of a stable and secure nation. To continue to deny hydro power's electric benefits and allow other non-renewable electric installations to be built is to place at risk the health and welfare of Sri Lanka.

"*The study found that the main economic impact of power interruptions, both planned and unplanned, is the loss of output in the industrial sector. These losses can be as high as US$81 million annually (0.65% of GDP) under a typical scenario (300 hours of planned outages) of imposing power interruptions such as those experienced during 2001. Also the impact due to unplanned outages can be as high as US$47 million (0.38% of GDP) in a typical year having 100 hours of unplanned outages. This is a significant economic loss especially in comparison to the 4.5% to 5% average GDP growth that has taken place in Sri Lanka during the last few years.*

Based on this study, the cost of un-served energy for the Sri Lanka system is estimated to be US$0.66 (Rs.59)/kWh for planned interruptions and US$1.06 (Rs.97)/kWh for

85 Source: Energy Information Administration, EIA website online under: httpc//www.eia.doc.gov [2004.11.15].

86 Further information is available in chapter 3.4 Sri Lanka's Energy Politic for the Future on p. 53.

unplanned interruptions. These costs are very high in comparison to the cost of power supplied to industry by CEB, which ranges from Rs.7.0/kWh to Rs7.5/kWh."[87]

Interruption Type	Cost of Un-Served Energy
Planned Interruption	US$0.66 /kWh
Unplanned Interruption	US$1.06 /kWh

Table 23: Cost of Un-Served Energy According to Interruption Type

It was found that 92% of the sampled industries have backup unit generating facilities to satisfy either their full or partial demand for power. The total backup generating capacity in Sri Lanka's electricity sector is expected to grow during the next five years as a result of continuing supply interruptions. Such a situation results not only in increased energy costs to industry but also results in increased environmental emissions, which would adversely affect the local environment, particularly in urban centres where most of these industries are located.

In Sri Lanka, the growing electricity demand has led to a precarious balance of supply and demand. It is also expected that poor power quality in the form of planned or unplanned power supply interruptions will have an adverse impact on the GDP of a country.

These findings emphasize the importance of reducing both planned and unplanned interruptions in the Sri Lanka power system. To achieve this objective the following actions for hydropower in general are recommended by USAID-SARI:

- **Enhancement of the reliability of Sri Lanka's big hydropower stations through improvement of turbine maintenance.**
- **On the generation side, regular and periodic maintenance of generator equipment is necessary to ensure generator unit availability. Generation protection schemes should be overhauled to help ensure secure operation and improved unit availability.**

Table 24: Actions for Hydropower in Sri Lanka to Reduce Interruptions[88]

More recommendations on how to reduce both planned and unplanned interruptions are available in Annex 7.3A.2.

3.3.1 Energy and Capacity Losses

Total system loss including technical losses like generation station use, transmission and distribution network losses, and non-technical losses such as non-metered consumers, amounted to approximately 21% of total generation in 1999. It is important to note that system losses have been increasing during the last three years. System losses were 18%, 19% and 21% of total generation in the years 1997, 1998 and 1999. Although these system losses

[87] Quotation from *Economic Impact of Poor Power Quality on Industry-Sri Lanka*, 2003, Prepared for: USAID-SARI/Energy Program, online under: www.sari-energy.org [08.10.2004]

[88] Source: ibid.

are significantly lower than in most other south Asian countries, they are still high compared with recognized international standards. One of the main reasons for these high losses is the large number of non-metered consumers, amounting approximately 300,000 while the extension of distribution lines beyond technical limits also has contributed to high network losses.[89]

According to CEB transmission and distribution system causes excessive energy and capacity losses due to overloading. The scope for improvement is estimated at 9%. However, projects to built new lines have long been delayed.[90]

3.4 Sri Lanka's Energy Politic for the Future

"Sri Lanka has no formal energy policy. There are no policy directives or plans to encourage sustainable use of biomass – the country's main source of energy. In the absence of a formal policy, pricing practices suggest imply default policies. Energy pricing has generally been aimed at providing affordable electricity to small consumers. However, direct state subsidies, such as those provided for grid extensions to rural areas are diminishing.[91]

A pricing policy for energy alternatives is significant to achieve both the economic and rational use of energy, because pricing can influence demand. In the Sri Lankan context, it is beneficial that relative prices between electricity and oil are such that electricity is preferred for motive power in industry; oil, or where possible, biomass, for heating purposes. This does not imply that there should be different tariffs for heating and motive power. Judicious pricing will generally make it financially more attractive to use electricity for motive power, while other direct burning fuels are better for drying and heating applications.[92]

Recently the government is responding to environmental concerns as it was in the proposed 140 MW Kukale Ganga hydro power project. It would have partly submerged the Sinharaja virgin forest and totally the Kalawana township, displacing 30,000 people. For this reason the project was scaled down from a reservoir scheme to a 70 MW run-of-river scheme.[93]

Another case is the 120 MW Upper Kotmale project, which would have tapped the water of the upper catchments area of the scenic Devon waterfall. This, in turn, would have reduced the water supply to the picturesque St. Claire's waterfall. The project was refused to approve the project by the Central Environmental Authority (CEA), "*based on CEBs failure to consider alternative designs as stipulated in the Environmental Impact Assessment"*[94].

The role of the private sector in finance, ownership and operation is increasing. What the government seems to want is the maximum power production in the shortest possible time. Because it became increasingly difficult in the past years for the government to secure finance through international banks and bilateral agreements private investment in power production was striven. Among the motivation offered by the government to support the

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[89] ibid.

[90] See *NIC Status: Energy Issues and Options*, Siyimbalapitiya, T, Colombo, 1994.

[91] Quotation from *Beyond big Dams, A New Approach to Energy Sector and Watershed Planning*, IRN, 1998.

[92] Source: *Determination of a pricing Policy for Energy,* Perera, KKYW, seminar paper, 1992.

[93] According to *The Spectre of Kukule Ganga*, Citizen's Report on Environment and Development to UNCED, Sri Lanka, 1992.

[94] Quotation from *Beyond big Dams, A New Approach to Energy Sector and Watershed Planning*, IRN, 1998.

private power generation is a price of Rs. 5-6 (US$0.05 – 0.06) per kWh of hydro power fed to the national grid.[95]

Although there is no limit on the minimum capacity of units allowed for grid connection CEB engineers say that they will not promote units below 25 kW.[96]

3.4.1 CEBs Generation Expansion Plan

Over the years, the Expansion of the Power System has been based on three essential principles:

1. ***"Maximizing the use of the only indigenous natural resource for power generation – hydropower.***
2. ***Installation of adequate thermal base load capacity (capable for running over a long period of time at low cost) – examples are 50 MW Kelanitissa plant and 80 MW and later 40 MW Sapugaskana Plant – to meet the shortfall in hydropower.***
3. ***Installation of gas turbines which can be procured and installed at shortest possible time and run as and when required. The gas turbines are cheaper to purchase but expensive to run."***[97]

Table 25: Three Principles of the Expansion of Sri Lanka's Power System[98]

The CEB Act No. 17 of 1969 states "it shall be the duty of the Board to develop and maintain efficient coordinated and economical system of electricity supply for the whole Ceylon (Sri Lanka)." Nevertheless, CEBs expansion plans do not emphasize the importance of small hydro resources to electrify off-grid areas. It tends more towards thermal power plants maybe also because of the influence of the petrol lobby prevailing around the world and even in Sri Lanka.

The Long Term Generation Expansion Plan covering 2003- 2017 prepared by the CEB suggests that the power generating capacity has to be increased by at least 750 MW by 2010 in order to meet the growing demand. It is expected that the capacity will be increased through a

- **200 MW medium-term thermal power plant in 2005,**
- **a 300 MW coal fired power plant in 2008**
- **and the 150 MW Upper Kotmale hydropower plant in 2009.**

Table 26: Capacity Increase Suggested by CEBs Long Term Generation Expansion Plan[99]

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[95] More information about pricing and costs of hydropower systems is available in chapter 6.8.

[96] Compare ibid.

[97] Quotation from *Hydro Power Development in Sri Lanka and Hydro power Pricing Issues*, S. Fernando, T. Siyambalapitiya, PhD, T.A.K. Jayasekera, 2001.

[98] Source: *Meeting Sri Lanka's Future Electricity Needs*, S. Fernando, CEB in ESD, 2002.

[99] Compare *Longterm Generation Expansion Plan,* CEB, 2003.

Additionally, there are ideas of using nuclear power transported from India. *"Considering the heavy dependence on imported primary energy resources for future electricity generation in Sri Lanka, a cable link between Sri Lanka and India for power transfer is likely to be beneficial once the economic viability is established. This is particularly important with India having the technical capability on nuclear power generation development, which can bring down the generation costs substantially."*[100]

It is obvious that the production prices play the main role in the national electricity expansion plan.

3.4.2 Electricity Sector Reforms

Electricity prices in Sri Lanka remain among the highest in South Asia, and power supplies remain unreliable and voltage fluctuations are considerable. Despite the high prices the electricity sector is operating at a loss. The miss of any new important investment in generation capacity in the past decades make power sector reforms urgent.

Since 1998 there is a program on power sector restructuring in Sri Lanka assisted by the World Bank and Asian Development Bank (ADB). The proposed electricity industry structure plans vertical separation of generation, transmission and distribution functions and aims to establish an independent regulatory for the industry. A new Electricity Act including these new structures has been drawn up and is to be presented to the Parliament of Sri Lanka.[101]

Actually some reforms have been implemented, but important follow up steps such as a satisfactory restructuring of the power sector into focused entities in electricity generation, transmission and distribution have yet to materialize. Delays in restructuring the power sector have delayed release of the second part of $30 million of an Asian Development Bank reform program. Key factors for the power sector should be[102]

- **adjusting tariffs,**
- **increasing private sector participation,**
- **strengthening regulation and the financial viability of the power sector.**

Table 27: Key Factors for the Power Sector

Over recent years, considerable progress has been made towards the establishment of an environment and a market for decentralised electricity supply through MHP, solar, wind and bio-fuels. They have proved themselves to be a reliable, cost-effective and environmentally desirable alternative to grid supplied electricity for small isolated communities. A study carried out by the ITDG, Energy Forum and Citizen's Trust resulted that the entire reform process has *"completely neglected the existence of off grid electrification systems and only focused on the national grid and the government utilities on the electricity generation, transmission and distribution systems. The electricity reform act, No 28 of 2002, says that licences are required for all electricity generating, transmission, and*

[100] Adapted from *Sri Lanka Energy Supply Status and Cross Border Energy Trade Issues*, Sri Lanka Managers Association and CEB.

[101] See *Power Sector Policy Directive,* Ministry of Power & Energy, Sri Lanka, 1998.

[102] Compare *Country Strategy and Program Update 2005-2006* - Sri Lanka, ADB, 2004.

distribution systems. Secondly, it prevents a single operator having two licence to carry out any of the above two operations at once. In a community based typical micro hydro system both generation and distribution is handled by the community (Electrical Consumer Society). In this context the micro hydro systems have no legally status to generate and/or distribute electricity….After the reforms there will be five distribution companies set up who will have exclusive rights to respective geographical areas. This can prevent communities to set up and run micro hydro electrification systems." [103]

The proposed reforms to Sri Lanka's electricity system seem to jeopardise one of the few success stories, the introduction of micro-systems to supply isolated communities. There are two main topics. First, the five distribution companies proposed would have exclusive rights to provide electricity in their franchise region. This could mean that they could expropriate the existing schemes and block proposals by remote communities to build new systems. Second, under the new system, companies generating power would not be able to supply this electricity to end consumers. In theory, this could mean that micro-systems, supplying only a few kW, could be forced to divide into two parts.[104]

"If the reforms are to proceed in anything like their current proposed form, clear unequivocal exemptions must be written in that allow existing micro-systems to continue in community ownership as an integrated operation, i.e., generation and supply to consumers within the same organisation. Isolated communities not yet supplied with power must be free to set up new micro-systems without the need for the approval of the distribution company whose territory they are located in."[105]

3.4.3 Government Regulations on Power Handling

Under normal conditions, there are no restrictions on the use of utility supplied electricity in Sri Lanka. However, during power crises, which result generally from poor hydropower generation, the CEB implements usage restrictions. They could include forbidding the use of national grid electricity for purposes of air conditioning and for advertising using neon display boards like it was in 2001. Presently there is no formal mechanism in place for effective end-user participation in the electricity supply industry. This will be improved with the electricity sector reforms and with the establishment of the Public Utility Commission. This commission will regulate the electricity sector in the future.[106]

It is observed by the author, that in all offices in Sri Lanka he has visited, the temperature was too low due to extreme use of air conditioning units. However, the ergonomic agreeable temperature is between 21° C and 22 ° C and should have a maximum of 26 ° C in the summer.[107]

In Annex 7.3A.1 general tips and tricks are presented on how to save energy and therefore cost. Especially air conditioning units consume lots of electricity. The annexed list helps to follow the right instructions for the air conditioner and gives many other important suggestions in order to reduce the electricity consumption in the office, at home or of devices.

[103] Quotation from *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* J. Gunasekera, Technology Programme Leader ITDG-South Asia, Nov. 2003.

[104] Compare *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

[105] Quotation from *ibid.*

[106] According to *Economic Impact of Poor Power Quality on Industry-Sri Lanka*, 2003, p. 14 f, Prepared for: USAID-SARI/Energy Program, online under: www.sari-energy.org [08.10.2004].

[107] Compare *Ergo online*, online under: http://www.sozialnetz.de/ca/ph/het/ [2005.01.19].

4 Physical Feature and Climate

Sri Lanka's central and south-western parts are characterised by heavy and continuous rainfall and an uneven terrain with steep and rolling landscape. This geo-climatic condition has led to the formation of a great deal of streams, radiating from the upper reaches of the mountains and merging downstream to form some of Sri Lanka's major rivers, such as Mahaweli Ganga, Kelani Ganga and Kalu Ganga. These major rivers as well as small streams in the upper areas offer considerable potential for hydroelectric power development.[108]

4.1 Relief

A central highland massive are in the southern half of the island and compromise a series of plateaux and peaks, the highest of which is 2,524 metres. While in many places the topographical feature is separated by well marked steep slopes the intermediate zone in turn is enclosed by a low-lying zone of lands. The shores are mostly sandy beaches but also lagoons surround the island.

On the basis of elevation and landforms, Sri Lanka could be divided approximately into five topographical areas.

- The Central Highlands
- The South-west country
- The East and South-east country
- Northern lowlands
- The coastal region

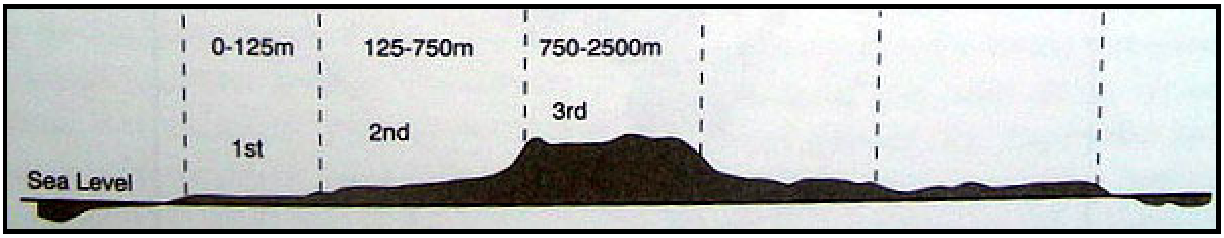

Figure 12: Diagrammatic Representation of Sri Lanka's Main Surface Configuration[109]

[108] Please note that the quality of some illustrations in this chapter is sometimes not high. This is due to the author's easy and fast scanning method through a digital picture camera during the period of literature enquiry.

[109] Source: National Atlas of Sri Lanka.

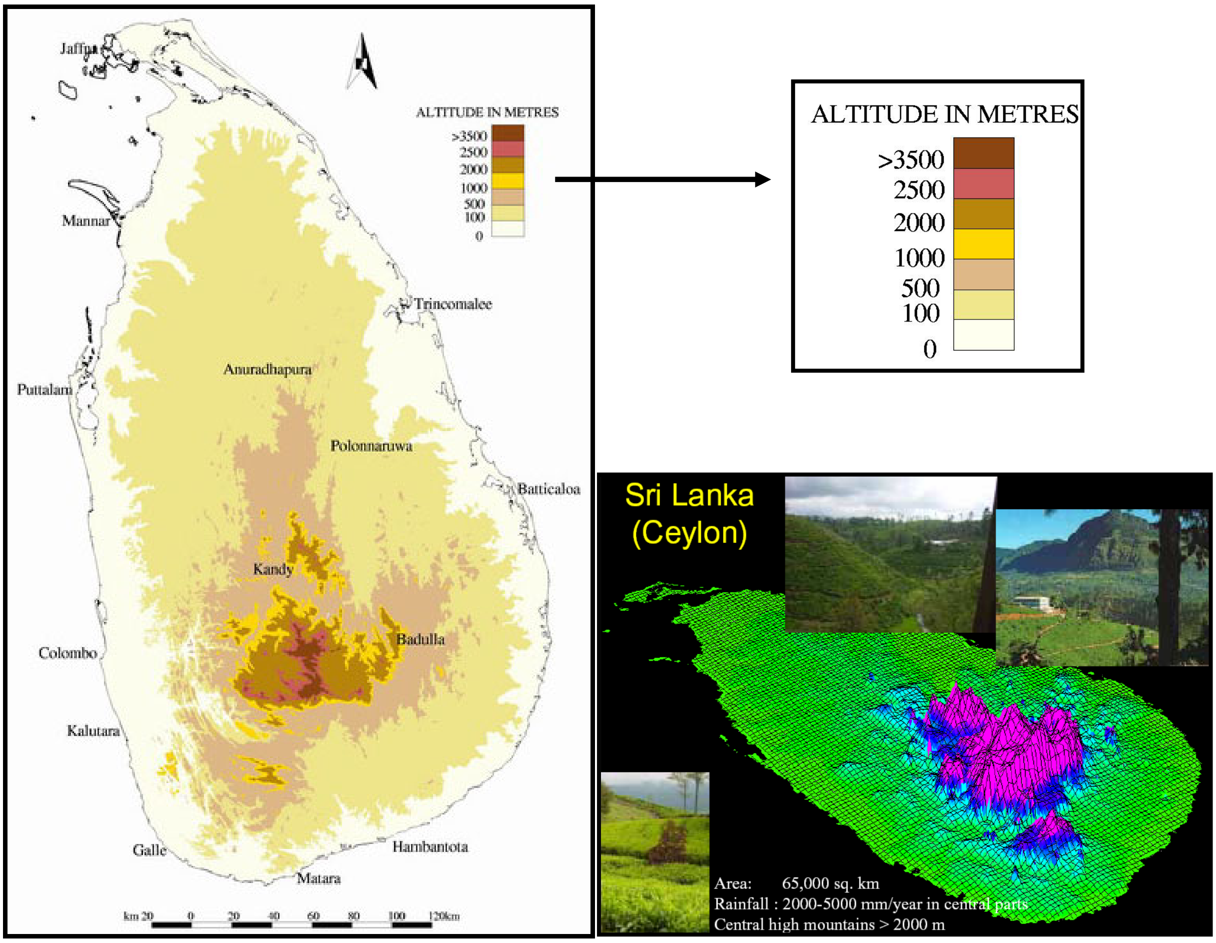

Figure 13: Schematic[110] & Computerized Representation of the Surface Configuration[111]

Areas of interest concerning hydro power development are the Central Highlands and the South-west country. The Central Highlands could be subdivided into two major landforms, on the one hand the Central Massif and on the other hand the Dumbara and Bulutota Massif which are detached parts of the Central Massif.

The Central Massif is a fairly compact unit bounded on the south by a mountain wall. On the north there is the traverse valley of the Mahaweli Ganga from Minipe to Kandy. This Central Massif consists of a *central backbone* of high plains and peaks which run from Bopatalawa to Pidurutalagala. Among the high plains of this backbone are, Elk Plains (Mipilimana), Moon Plains (Hawaeliya), Horton Plains (Bopatalawa), Kandapola Plains (Sitaeliya) and Ambewela Plains. While Pidurutalagala is with 2,524 m the highest point of Sri Lanka, Totapolakanda (2,357 m) and Kirigalpotta (2,395 m) are the other two peaks in this backbone area. Hatton (Ambatalawa) Platea and the Uva basin are the other two important elements of the Central Massif.

It is raining significantly in the South-west part of Sri Lanka. Fig. 14 shows a generalised rainfall map of Sri Lanka.

110 Source: http://iri.columbia.edu/~lareef/wcsl/SriLankaMay2003Weather.html [2004.12.18].

111 Source: *Role Playing Game Approach*, J. Valasquez, S. Herath, p. 207, 2002.

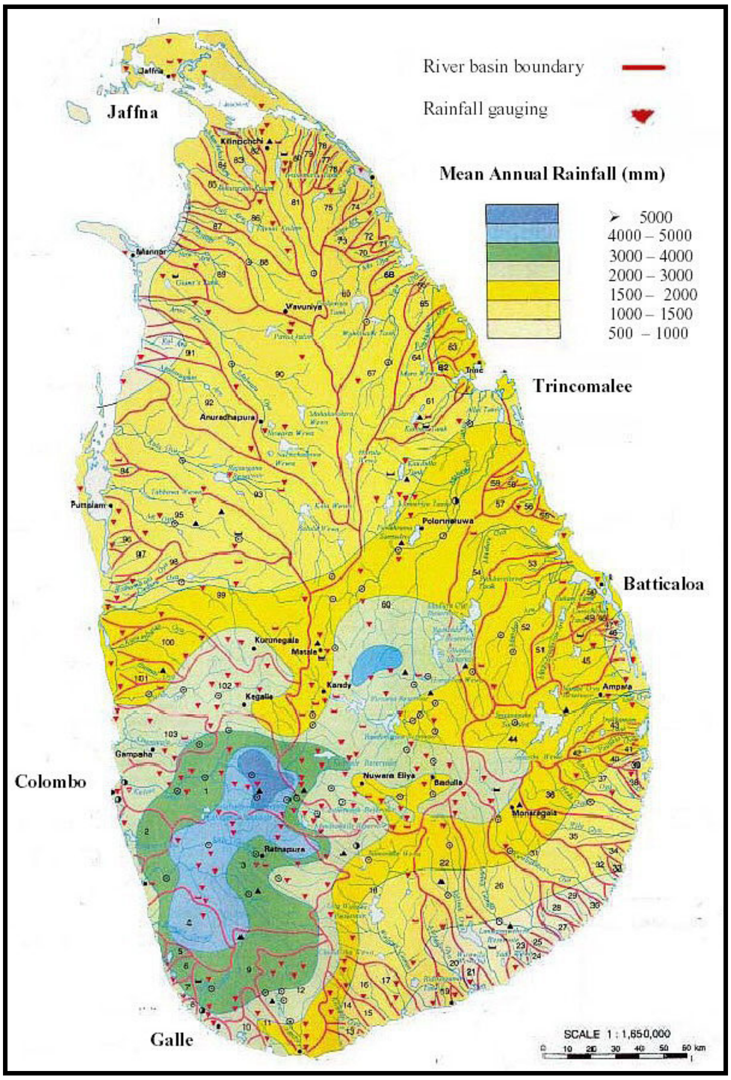

Figure 14: Generalised Rainfall Map of Sri Lanka, source: Somasekeram (1997)

4.2 The Rain Climate

The country has a variety of climates dependent upon the altitude and three types of rain climate, the monsoonal, convectional and depressional[112]. There is a division into three districts areas, the wet zone, i.e. the south-west sector, the dry zone of the north and east, and the up-country or South-central highlands. In the dry zone, the annual rainfall varies from 1015 mm to about 5 mm, where other parts experience intermittent and heavy rains.[113]

Monsoonal rains take place during the period of the two contrasting Asian monsoon wind systems, namely the south-west (SW) and north-east (NE) monsoon. This monsoonal rain is responsible for the annual rainfall. Convectional rain takes place during the transitional period from one monsoon to another, mostly in the afternoon and evening and appears to be experienced anywhere over the island. Low pressure rains are more regular in the second monsoon period of October and November. They are responsible for a large part of the

[112] Depression indicates area of low pressure

[113] See *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999, p. 6.

rainfall during these two months. Therefore, Sri Lanka's rain climate is described by four distinct seasons:

1. March – mid May : First inter-monsoon season
2. Mid May – September: South-west monsoon season
3. October – November : Second inter-monsoon season
4. December – February : North-east monsoon season

According to this classification, *"the two monsoons last over 62.5% of the year while intermonsoon seasons account for the balance. However, under no circumstances does the monsoon regime over Sri Lanka exhibit homogeneous climate conditions over the whole island. Besides the fundamental difference of the structure and rainfall conditions in both the monsoon seasons, the general climate also exhibits a considerable spatial differentiation as a result of the Central Highlands. Although these highlands have no great vertical extension (highest elevation 2,524 m at Piduratalagala), they form an* orographic barrier *across the path of monsoonal air masses and winds. Thus, the highlands not only perform the role of climatic-shed, but also establish the regional differentiation of the Highlands into windward and leeward side, including the flanking lowlands."*[114]

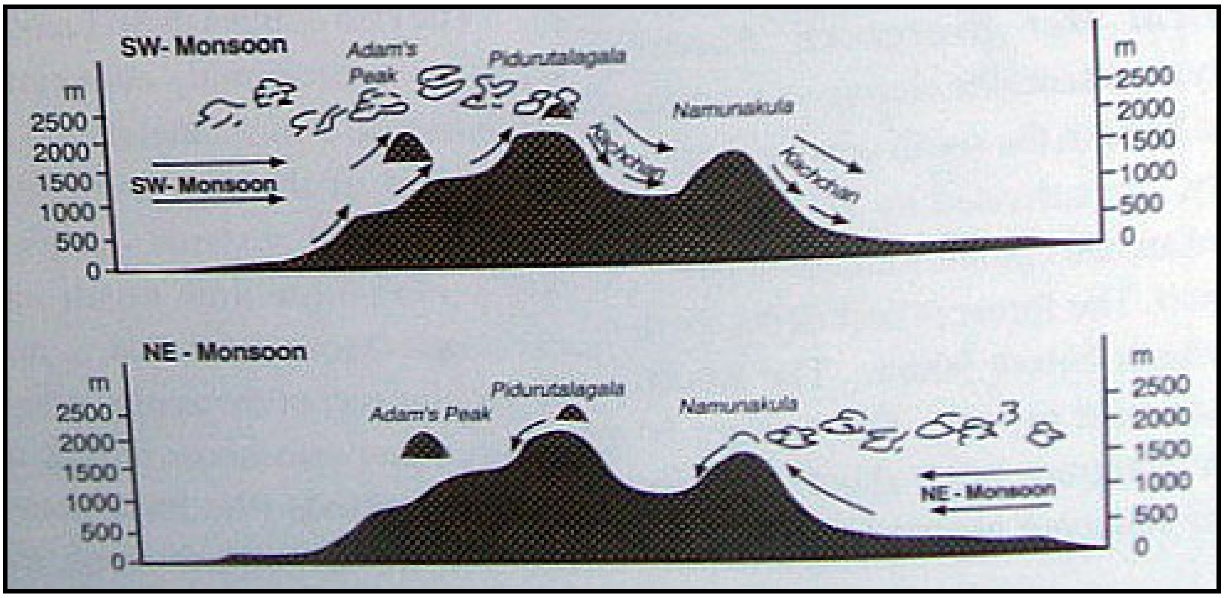

Figure 15: Windward & Leeward Sides During the Two Monsoons[115]

The effect of the highlands is changing in nature because of the wind directions of the two monsoons. For example are those parts of the highlands on the leeward side during one monsoon on the windward side (Fig. 15), and vice versa. This phenomenon is also verified in Fig. 16 where the central highlands annual rainfall pattern in Hanguranketha (on the windward side during north-east monsoon) and Rozella (on the windward side during south-west monsoon) are compared.

[114] Quotation from ibid.

[115] Source: *Agro-climate of Ceylon*, Manfred Domros.

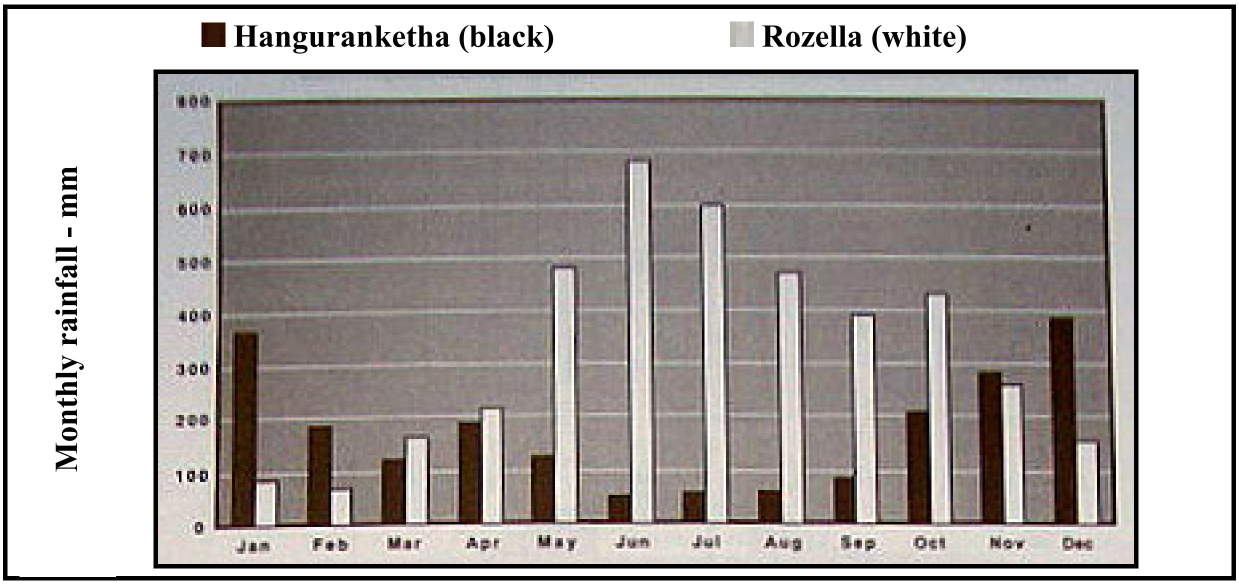

Figure 16: Rainfall Rhythm on Eastern & Western Slopes of the Central Highlands.[116]

Besides this larger regional consequence, there is also the micro-regional relief of the Central highlands modifying the windward and leeward side climates. This results sometimes in far-reaching small-scale difference from the widespread, large-scale climatic circumstances.

In spite of the small area of the island there is an extraordinary variation in precipitation, *"amounting to over 5,500 mm in the wettest part and about 1,000 mm in the driest area. Thus the absolute range of rainfall amounts to 4,500 mm."*[117] The south-west part with the Central Highlands is clearly the wettest area of the country (See also rainfall map, Fig. 14). Within the islands south-west sector the absolute maximum of precipitation is in the western hills of the Highlands – at lower altitudes between 300 m and 1,000 m (Maliboda, Watawala and Ginigathhenna). From this small area of highest rainfall precipitation continues to decrease over 1,000 m reaching about 2,000 mm on the high plains around Nuwara Eliya with an altitude of proximately 2,200 m. However, rainfall is more gradual towards the coastal plain in the south-west.

On the eastern hills of the Central Highlands the precipitation *"drops to 2,000 mm and even below in the Uva Basin. A moderate rainfall ~ 2,500 mm, is recorded in the eastern mountainous region of Sri Lanka comprising the Lunugala Range and Namunakula Massif. A very high rainfall of about 4,000 mm is recorded on the eastern flank of the Knuckles Range (Hendon Estate) but is spatially restricted to a small area."*[118] This phenomenon is shown in the following figure however, without the Knuckles Range.

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[116] Based on rainfall data for 1931-1960 – Dept. of Meteorology, report for 1971

[117] Quotation from *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999, p. 7.

[118] Quotation from ibid.

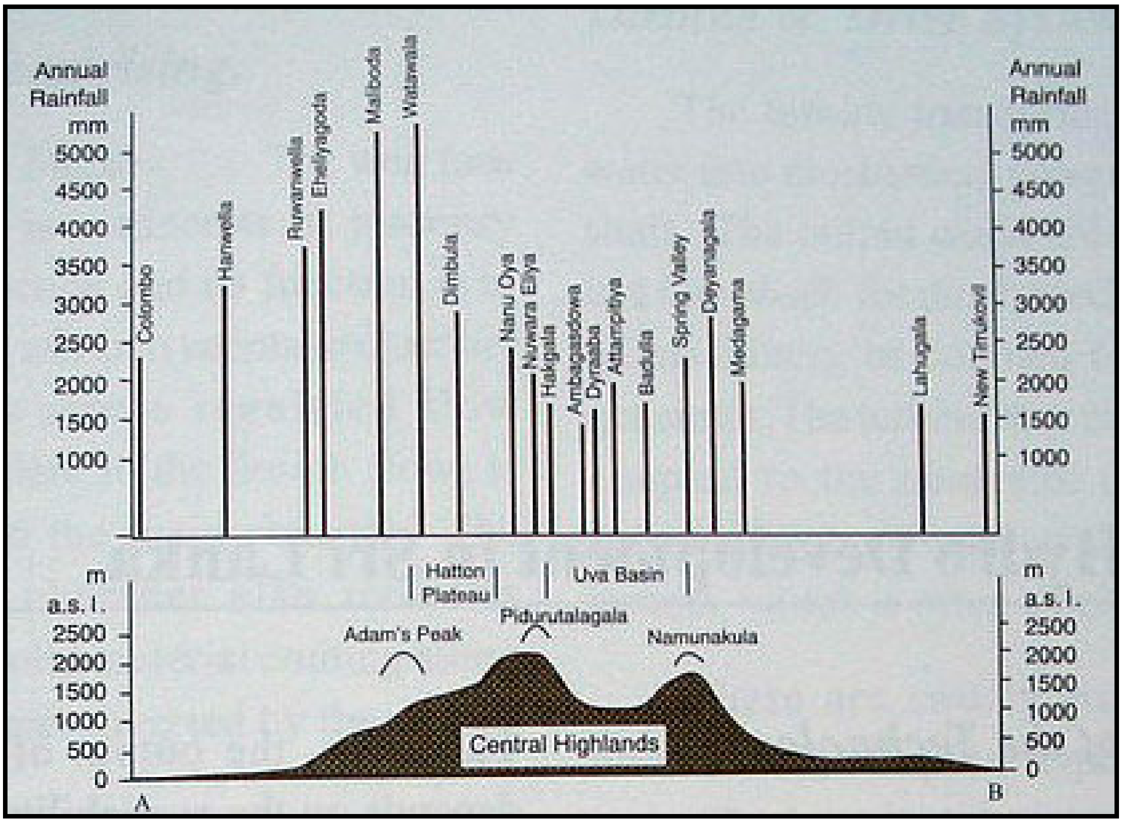


Figure 17: Variation of Rainfall across the Central Highlands.[119]

Obviously, the rainfall regime in most sections of the mountainous area of the island, especially in the western hills is characterised by a constant and well distributed pattern for about nine month of an average year. This wet climate together with the uneven ground has formed many streams radiating from the mountains. These conditions offer considerable potential for hydroelectric power development, not only large hydro power but also small-scale ones.

To have an impression how much the rain can influence the water flow of a river, the following pictures are chosen. They are taken in the Central Highlands near to the city of Ratnapura, before and after rain falls in the morning and afternoon.

Figure 18 a & b: Same River before & after Rain Fall, source: Author (2004.12.14.)

[119] Source: from ibid. p.8.

5 Small-Scale Hydropower – Basics and History

A widely held perception of hydro power is of billion dollar projects involving construction of huge concrete dams to impound sufficient water in a man-made lake of a capacity such that it will smooth out the seasonal fluctuations in flow of the river(s) that feed it.

In some cases massive and controversial projects of this kind were constructed, especially in Africa (dams such as Kariba, Aswan, Volta, Cabora Bassa) which involved flooding hundreds of square kilometres to store cubic kilometres of water. Today, in an era of greater sensitivity to the environment, such projects have tended to give all forms of hydro power a bad name. This is because the huge artificial lakes have had significant negative environmental impact in terms of displaced populations, loss of land and even considerable greenhouse gas production due to rotting vegetation in the lakes. Many of these systems are often not totally sustainable, since the lakes can gradually silt up, eventually to become malarial marshes with greatly reduced capacity for water storage. Having said that, it must also be stressed that no large-scale method of energy production can be entirely without environmental impact, and in many cases large hydro schemes, despite their shortcomings, might be a lot less harmful in general than most other methods of power generation.

To this day most hydro power capacity consists of large and medium-sized plants of many megawatts each. However there is a growing interest in so-called “small hydro power” or SHP, defined internationally as any hydro installation rated at less than 10 MW. A sub-set of this is micro-hydro, which covers systems of less than 500 kW.

5.1 How Hydropower Works

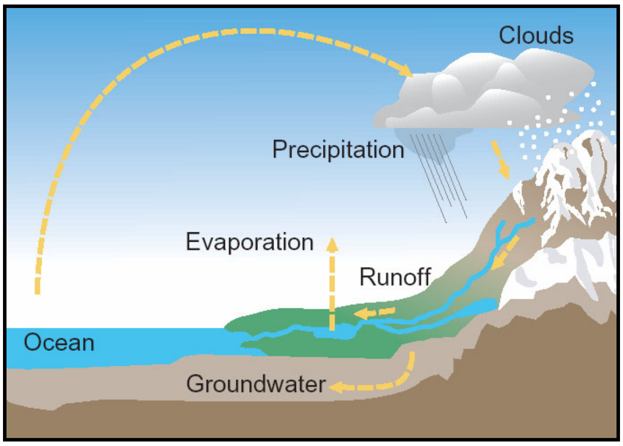


Figure 19: The Hydrologic Cycle

Powered by the sun, water moves constantly through a global hydrologic cycle. It evaporates from oceans and lakes, forms clouds, precipitates as snow or rain and then flows back to the ocean. The energy of this water cycle is tapped most efficiently with hydropower by converting falling water into electricity. Hydropower is renewable because it does not use more water than it is produced by nature. A good turbine will give back in work from 75 to 83 % of the energy applied to it; whereas the best thermal power plants will barely give 52 %.[120]

[120] Source of figure: online under: www.hydropower.inel.gov [2004.11.16]

5.2 Classification

In broad terms, a small hydropower is an installation where falling or flowing water is used to generate electricity by means of one or more turbines and generators having a bottleneck capacity of 10,000 kW or less per station. Finer distinctions of micro, mini or small are sometimes made but there is no universally accepted definition and the practice, at present, differs from country to country. The table below outlines the categories used to define the power output from hydropower. This report will concentrate mainly at small and micro hydro power.

Large- hydro	More than 100 MW and feeding into a large electricity grid
Medium-hydro	15 - 100 MW - feeding a grid
Small-hydropower (SHP)	100 kW - 10 MW - usually feeding a grid
Micro-hydropower (MHP)	Ranging from a few hundred watts for battery charging or food processing applications up to 100 kW; usually provided power for a small community or rural industry in remote areas away from the grid.
Pico-hydro	Less than 100 watts

Table 28: Classification of Hydropower by Size

5.3 An Outline of the Technology

Small hydro schemes in Sri Lanka are normally designed to operate for a minimum of 20 years if they are properly looked after. They are usually "run-of-the-river" types meaning that they do not require a dam or storage facility to be constructed. Therefore, this type of hydro power avoids the damaging environmental and social effects which larger hydroelectric schemes cause. The typical layout of a "run-of-the-river" scheme is shown in figure below.

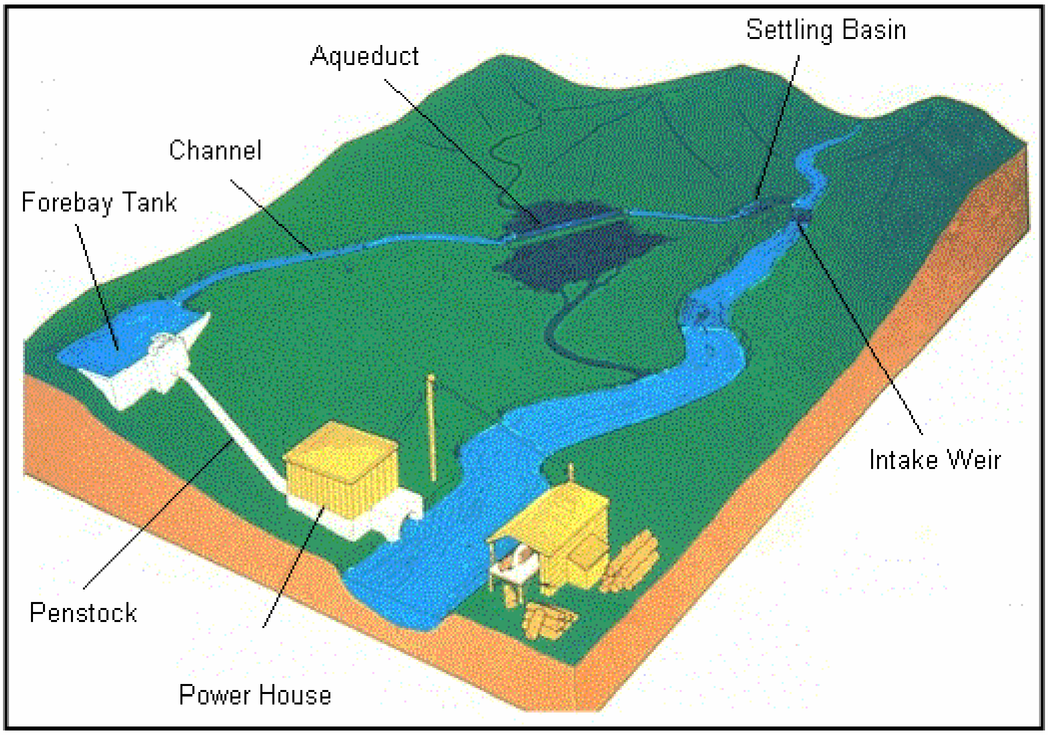


Figure 20: A Typical "Run-Of-the-River" Micro Hydropower Scheme

They simply channel water from the stream or river through a settling basin, which helps to remove sediment that could harm the turbine. The water is diverted through a masonry or concrete weir built across the stream. The water then flows into the forebay tank where it is directed downhill through a pipe called penstock and "dropped" in to a turbine. This specially designed turbine drives an induction generator, which is a standard induction motor converted to run as a generator. The scheme provides 230 V AC current to households via a distribution line.

Sub systems of a small hydropower system can be classified into following areas[121]:

[121] The images on right side on the next page are taken by the author during his work in Sri Lanka in 2004. The MHP plant is located in a remote community in Ratnapura.

5.3.1 Civil Works

Weir and Intake:

The weir is a masonry or concrete construction. Its purpose is to divert water into an intake chamber from where a regulated flow is let into the main channel. Larger solid material which is coming along with the water diverted by the weir is removed by the intake chamber.

Figure 22: Forebay Tank

Main Channel

The main channel is developed to convey the delivered amount of water up to the point of supplying it to the power house. In figure 23 you can see a main channel of a MHP plant in Ratnapura.

Figure 23: Main Channel

Silt Basin and Forebay

The settling basin removes anything falling into the main channel and residual finer silt (Fig. 24). The forebay has the function of maintaining a stable water level above the penstock mouth (Fig. 22). These two structures are often built together.

Penstock

Water under pressure from the forebay is carried by the penstock into the turbine. The penstock should be supported at regular intervals and well anchored to the ground bends.

Figure 21: Penstock, source: GTZ

Figure 24: Silt Basin

5.3.2 Electro-Mechanical Work

Turbine and Drive System

The energy in the water is transformed into mechanical power at the turbine shaft. The output could either be coupled to an electrical generator or supplied to a line shaft[122] for direct mechanical driving of machinery. If the turbine speed is high enough, the turbine can be directly coupled to the generator or otherwise through a drive system, which is often a belt drive.

Figure 25: Turbine-Generator Connection through Belt, Ratnapura, source: Author

There are many types of turbines used for hydropower, and they are chosen based on their particular application and the height of standing water -referred to as "head" - available to run them. The turning part of the turbine is called the runner. As shown in the table below, turbines are broadly divided into three groups; high, medium and low head, and into two categories: impulse and reaction.

	Head Pressure		
Turbine Runner	**High**	**Medium**	**Low**
Impulse	**Pelton Turgo Multi-jet Pelton**	**Cross Flow Turgo Multi-jet Pelton**	**Cross Flow**
Reaction		**Francis Pump-as-Turbine (PAT)**	**Propeller Kaplan**

Table 29: Classification of Turbines[123]

The most common turbines in Sri Lanka are as follows:[124]

[122] A line-shaft is a single overhead shaft laid across the factory carrying a number of pulleys each of which is connected via belt-drive to the process machinery.

[123] Source: Micro-hydro Design Manual, IT Publications, 1993.

[124] The following images have the source: www.trinityhydro.com/ peltonturbine1/en/index.asp [2004.10.16].

Pelton Turbine

A Pelton turbine has one or more injectors of water impinging on the buckets of a runner which looks like a water wheel. Pelton turbines are used for high-head sites between 15m to 1,800m (50 feet to 6000 feet) and can be as large as 200 MW.

Figure 26: Two Jet Pelton Turbine

Francis Turbine

A Francis turbine has a runner with fixed vanes, usually nine or more. The water enters the turbine in a radial direction with respect to the shaft, and is discharged in an axial direction. Francis turbines will operate from 3m to 600m (10 feet to 2000 feet) of head and can be as large as 800 MW.

Figure 27: Francis Turbine

Propeller Turbine

A propeller has a runner with three to six fixed blades, like a boat propeller. The water passes through the runner and drives the blades. Propeller turbines can operate from 3 m to 90 m (10 feet to 300) of head and can be as large as 100 MW. A Kaplan turbine is a type of propeller turbine in which the pitch of the blades can be changed to improve performance. Kaplan turbines can be as large as 400 MW.

Figure 28: Kaplan Turbine

Cross Flow Turbine

This type of turbine is used very often in Sri Lanka. Because of the simple design local manufacturing is possible without the need for sophisticated manufacturing facilities. Therefore the production costs are low compared with other turbine designs.

Figure 29: Cross Flow Turbine,

"The difference between impulse and reaction can be explained as follows: "The impulse turbines convert the kinetic energy of a jet of water in air into movement by striking turbine buckets or blades - there is no pressure reduction as the water pressure is atmospheric on both sides of the impeller. The blades of a reaction turbine, on the other hand, are totally immersed in the flow of water, and the angular as well as linear momentum of the water is converted into shaft power - the pressure of water leaving the runner is reduced to atmospheric or lower."[125]

Load factor

The load factor describes the amount of power used divided by the amount of power that is available if the turbine were to be used continuously. As the "fuel" for hydropower generation is free the plant becomes more cost effective if it is run for a high percentage of the time. The plant factor will be very low if the turbine is only used for domestic lighting in the evenings. If the turbine meets domestic demand during the evening, provides power for rural industry during the day and maybe pumps water for irrigation in the evening, then the plant factor will be high. Already during the planning stage it should be taken into account to ensure a high plant factor if the scheme is to be cost effective. Many schemes use a "dump" load when an excess is produced. Instead of wasting energy, water heating, storage heaters or storage cookers could be operated with this excess energy.[126]

Generator, Controls, Switchgear and Electrical Transmission

Mechanical power is transformed into electrical power through the generator. A set of controls and switchgear is needed to monitor the plant output, maintain the quality of electrical power and to ensure safety of the plant and service personnel. A transmission line feeds the output to the user's premises with or without transformers, which depends on the specific site conditions.

Figure 30: Controls and Switchgear of a MHP Plant in Ratnapura, source: Author

Like petrol or diesel engines, water turbines vary in speed when load is applied or relieved. Although not such a great problem with direct shaft power applications, this speed variation seriously affects both frequency and voltage output from a generator. Traditionally,

[125] Quotation from: Micro Hydro Power, ITDG Technical Brief, 2000.

[126] Compare ibid.

complex hydraulic or mechanical speed governors changed flow when the load varied, but more recently an electronic load controller (ELC) has been developed increasing the simplicity and reliability of modern MHP plants. The ELC continuously adds or subtracts an artificial load. This prevents speed variations so that in effect, the turbine is working constantly under full load. Additionally, the ELC has no moving parts, is very reliable and almost free of maintenance. The coming of ELC has allowed the introduction of simple and efficient, multi-jet turbines, no longer burdened by expensive hydraulic governors.[127]

5.4 Flow Duration Curve

Any river has different flow, which vary during the year and from year to year. Therefore, to estimate the output of a micro hydro plant, it is necessary to know the percentage time that a particular flow rate persists in the river (exceedence[128]). A Flow Duration Curve (FDC) represents the relationship between the flow rate in a river and the duration of its availability. While the exceedence is described by the X- axis, the river flow rate is described by the Y- axis. About 10 years of daily river flow data analysis is necessary to get a reasonable FDC for SHP output estimations.

"FDC is converted into a Normalised FDC by dividing the flow rates values of the FDC by the catchment area of the river. This is a process of adjusting it to unit catchment area. Thus, the Y- axis of a normalised FDC has the unit – l/s per sqkm. The stream flow of a catchment of any size could then be estimated by multiplying the normalised flow rates obtained from the curve by the catchment area."[129]

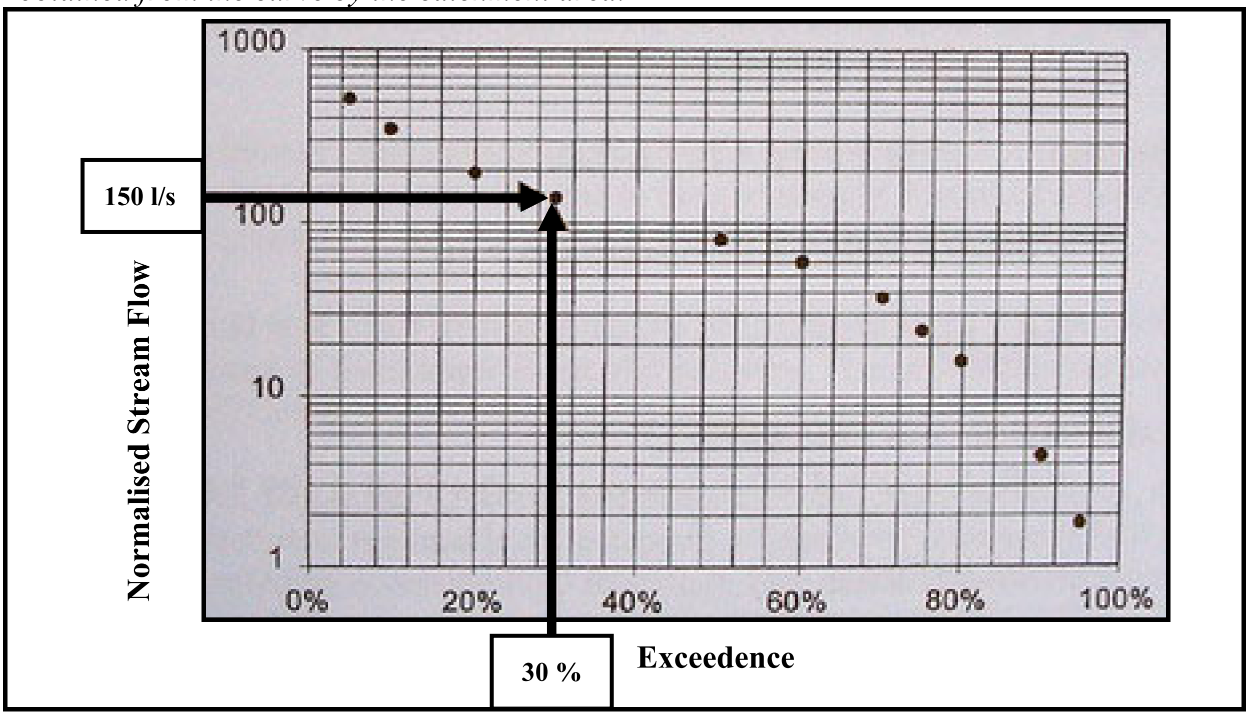


Figure 31: Normalized FDC of Sitawaka Ganga in Sri Lanka, source: ibid.

[127] Compare ibid.

[128] Exceedence is defined as the percentage time of the year that the river flow is equal to or greater than a particular flow rate. For example, for 30 % of the year, the normalised flow rate of Sitawaka Ganga is approximately 150 l/s per sqkm.

[129] Quotation from *An Assessment of Off-Grid Micro Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 2000

5.5 Sample Calculation of a typical MHP scheme in Sri Lanka

Following a sample calculation is presented in order to have a background about the physics and mathematics in the phase of planning. The example is based on ITDG literature. It is the calculation for the Village Atula Uda in the District Kegalle.

Catchment area	=0.775 km
Head	=100 m
Design Flow	Catchment Area * Design flow per sq. km (Taken from the normalized Flow Duration Curve FDC) =0.775 * 24 = 18.5 l/s
Installed capacity (P_{el})	$=Q * r * g * H * h * 10^{-3}$ $= 0.0019 * 1000 * 9.81 * 100 * 0.5 * 10^{-3}$ = 9.1 kW
Estimated annual electricity output in kWh	= (P_{el} * 0.75 * 8760 (hours per year) + P_{el} * 0.125 * 8760) * 0.9 =62.937 kWh
No. of house holds in the village	= 39
Power demand of the village	= 39 * 100 W = 3900 W = 3.9 kW
Available Power	= 9.1 kW
Households fed by the stream in %	= 3.9 / 9.1 * 100% > 1 =>100% The total power demand of the village could be supplied from this MHP project
Estimated scheme cost	= US$10,800, This amount is estimated by author basing on US$1,200 each installed kW. This is according to the past 10 years of ITDGs experience in micro and small hydro power generation field.

Table 30: Sample Calculation of Installed Capacity & Electricity Output of a MHP Plant[130]

5.6 Environmental Impacts of Small-Scale Hydropower

As in most cases SHP and MHP is "run-of-river" the impacts are relatively small. They are usually "run-of-the-river" types meaning that they do not require a dam or storage facility to be constructed. The civil works serve the function of regulating the level of the water at the intake to the hydropower plant. Therefore, this type of hydro power avoids the damaging environmental and social effects which larger hydroelectric schemes cause. Of course, there are some environmental problems in Sri Lanka, these are stressed below. But MHP systems in Sri Lanka do not normally have a harmful effect on the environment, but the environment can affect also the project. *"Therefore, the possibilities of the project being*

[130] Adapted from ibid.

damaged by floods or landslides must be explored. If there is such a possibility, then the project site must be changed."[131]

According to a case study made by the ITDG in 1999 (an *Environmental Impact Assessment of Micro Hydro Project Site)* basing on 11 installed MHP systems "there were no major ecological impacts observed at any of the sites visited."[132]

The above mentioned study identified the following environmental impacts:

1. Eco system changes
2. Impediment to upstream migration of fish
3. Velocity Changes and riparian vegetation
4. Sedimentation
5. Changes in Downstream habitat conditions
6. Reduction of water flow in the dry season
7. Soil erosion
8. Disturbance and felling of trees
9. Entry of fauna into the forebay tank
10. Distribution wires
11. Noise pollution
12. **Sites for power house, forebay tank, headrace and tailrace channels**

Table 31: Environmental Impacts of MHP Systems, Identified by ITDG (1999)

Eco System Changes

Any hydroelectric construction causes changes in the ecosystems. After altering habitat conditions, a new pattern of biological activity will emerge. This will influence plants, wildlife until a new equilibrium is established. On the one hand can such changes adversely affect some populations and on the other hand be positive to others.

Impediment to Upstream Migration of Fish

Hydropower projects form a physical barrier to the upstream and downstream migration of fish species. *"There is no provision made for the fish movement in the technology used at any of the sites observed, nor any of the sites facilitated by the ITDG to date, in weirs spanning the full width of the water course. Weirs which do not span the full width of the water course naturally leave room for faunal movement. Some fish do come in to the turbines vie the head race channel or the penstock, but this is very rare, as all sites visited had protective mesh fixed across the mouth of these channels."*[133]

While there are no anadromous fish species such as salmon, nor commercially important game fish species such as trout in Sri Lanka's rivers, there may be several resident migratory fish species being affected.

[131] Quotation from *Financial Guidelines for Micro-Hydro Projects*, ITDG Nepal publications, 1997.

[132] *Environmental Impact Assessment of Micro Hydro Project Sites*, Thiruni Ramadan, ITDG 1999.

[133] Quotation from ibid.

Furthermore, other river fauna such as otters as well as movement of amphibians, molluscs or insects are not affected by weirs.

Velocity Changes and Riparian Vegetation

Velocity changes are observed mainly in weirs extending the full width of the river. The velocity of the flow is a key environmental factor shaping the ecology of the micro-habitat in aquatic environments. Upstream habitat conditions will be changed if a drastic decrease of the flow velocity happens. This could affect riparian vegetation, and result in long term changes in the composition of species in that part of the river. *"Some of the groups of organisms affected would be fresh molluscs, insects (larvae), freshwater hydrozoans, fish, freshwater plants and algae. The effect would gain in significance in cases where the same stream is tapped for more than one micro-hydro scheme. Changes in riparian vegetation upstream were observed in two of the sites visited."*[134]

Apart from the vegetation close the ground, there was no change in the tree cover or species of trees between these areas observed.

Sedimentation

"Stagnation of water upstream of the weir (particularly close to the naks of the water way) would also adversely affect water quality, and cause an increase in siltation/sedimentation, and the amount of particulate matter suspended in the water."[135]

This situation was observed two times in the ITDG study.

Changes in Downstream Habitat Conditions

As the weir heights are comparatively small and water flow is not greatly affected by the weir, no significant changes are observed in the surveyed downstream habitat conditions.

Reduction of Water Flow in the Dry Season

This is notably where the water is extracted in a distance from where it is discharged back into the river. The short stretch of bypassed river can run dry or look unsightly, especially in the dry season ranging from February to April. If the stream bed is dry for a period of time it would affect the survival of species of organisms which do not have an encysted / dormant stage in their life. New hydropower systems should be designed to leave sufficient water bypassing the turbines. This is not difficult except in the dry season.

"In addition, stream flow could be reduced due to irrigation withdrawals or for other stream uses. The presence of many authorised as well unauthorised intake points for potable water and irrigation will make it difficult to separate out the impact due to the impact of the micro-hydro schemes alone."[136]

[134] Quotation from ibid.

[135] Quotation from ibid.

[136] Quotation from ibid.

Soil Erosion

Soil erosion was observed sometimes, but the magnitude of it reduces with time, as plants re-grow over the area stabilising the soil. The most amount of soil erosion can be expected in the laying of the penstock, as this is usually located on sloping ground.

Disturbance and Felling of Trees

The path of the penstock is again expected to cause most erosion as removal of vegetation and felling of trees is most likely.

Entry of Fauna into the Forebay Tank

In order to protect turbines from all the debris that is commonly found in rivers, whether natural (such as leaves, branches and even tree trunks) or man-made (supermarket trolleys, plastic fertiliser bags or general garbage a wire mesh or net is put in the mouth of the headrace channel or penstock. Local people report of occasionally fish slipping through into the forebay tank.

Distribution Wires

ITDG observed many distribution wires running across the landscape, sometimes crossing each other. Sometimes, the wires were strung very low or were sagging having weak supports or from tree to tree. This could cause hazard as well as an obstruction, even if the wires are insulated. The insulation could leak or break.

If many distribution wires lead out from the power station, an obstructive visual effect through criss-crossing of wires is observed.

Noise Pollution

Of course there is a constant background noise in machinery operating in the power house. Mostly, this can be carried across a radius of up to 0.5 km. But it seems to be not as disturbing as it could be, due the low and fairly constant frequency and also because it was sighted a “**Trogon**”, an uncommon endemic forest species – a bird that is not often seen outside undisturbed forest – seated on a branch within 10 metres of the power house, while it was in operation.

Sites for Power House, Forebay Tank, Headrace and Tailrace Channels

Unfortunately, there are many small reserves protected under the jurisdiction of the Forestry Department in common MHP areas. *“If a site does fall within a protected area, the laws laid down in the relevant legislation will have to be followed, and more attention paid to reduce disturbance of natural fauna and flora.”*[137]

[137] Quotation from ibid.

5.7 Protection, Mitigation and Enhancement Strategies

However, suitable design techniques make all these problems capable of being mitigated. The end product is a remarkably long-lasting, reliable and potentially economical source of clean energy.

Additionally, these three groups can help to improve the environmental effects of a SHP development.

Protection refers largely to land areas surrounding a hydro project including natural habitat which need to be protected by legislature, for example.

Mitigation strategies are either used to reduce an existing or unavoidable negative environmental effect or to compensate the caused damage. A mitigation measure would be, for example, the artificial restocking of a part of a river/stream, where the population of this particular species of fish has been drastically reduced due to a SHP system.

Enhancement methods are taken in order to minimize or alleviate impacts or maximise positive effects on the environment. Such enhancements minimize technically or naturally non-desirable effects by altering habitat conditions e.g. through creating a fish passage.

Another enhancement method is the following.

5.8 River Water Cleaning Through Hydropower Stations

In order to protect besides the turbine also the river water from all the debris that is commonly found in rivers, whether natural (such as leaves, branches and even tree trunks) or man-made (supermarket trolleys, plastic fertiliser bags or general garbage) a screen is put in the intake area. There are even self-cleaning intake screens available in the market (p. 111).

In the developed world, garbage collection and disposal carried out at a hydro installation is serving to clean up a river considerably. Everyone downstream is benefiting from this river-cleaning method, *"but usually at considerable expense to the operator. A major operating cost element is cleaning these screens, especially in low head situations where large flow rates pass through. Understandably, though slightly unjustly, the hydro-plant operators are usually prohibited by law from returning the rubbish collected on their screens back into the river.*[138]

From this point of view MHP and SHP is playing an important role to maintain the natural quality of the river water. River water is very important for every country as fresh water has became hot good in the actual period of our "blue planet" and rivers are the veins of this planet. Only 0.3% of the whole water on the planet earth consists of fresh water.[139] Fresh water is source for irrigation, drinking water for six billion people and has more other functions like e.g. keeping the flora and fauna alive. The rivers play hereby the important role as they are the veins of the earth.

An important scope for the future could be to investigate which other ways exist to purge anything from the water, which could have negative effects in any matter. Hydropower stations could be used as a station for a remarkably long-lasting, reliable and potentially economical source of clean and fuel-free energy and as a counter we can clean the water

[138] Quotation from *small hydro deserves to have its development accelerated in most parts of the world,* Peter Fraenkel, Renewable Energy World, March 1999.

[139] Compare *Wasser, das Lebenselexir. Wie Sie mehr aus dem wichtigsten Lebensmittel machen*, Ulla Kinon, Germany 1998.

within the same station through new kind of measures. Consequently, infrastructural costs can be shared through energy generation and cleaning in one and the same station.

Additionally, a lot of hidden economic costs are saved, too. On the one hand energy generated by fossil fuels have a proven bad impact on the environment, not only through CO2 emissions, there are also many other harming gases and particles emitted. Besides, even wars are made, to have the control over this "black gold", and wars cost a lot of money. On the other hand a cleaner water represents also high advantages for the cultivation sector and most important, for the population and flora and fauna.

Can Water Save Information?

More and more people consider not only the physical or chemical qualities of water. They believe that water can also save information, due to its complex and extraordinary structure (hydrogen bonds and dipole etc.). Dr. Masaru Emoto has been conducting numerous experiments in the past twelve years. Based on the same effect of different crystalline structures of snow, he made magnified pictures of frozen water crystals, of water collected from springs and cities or even water which was before stimulated by music, words and even feelings. The experiments show through high resolution pictures, that water can save information and so, has different qualities in terms of "good or bad information".[140]

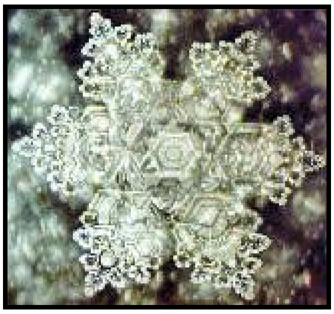
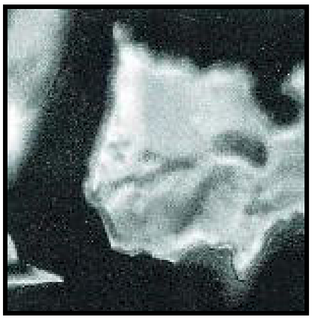
		
Spring water of Saijo, Hirosh: The area around this city is well known for is good quality fort he Sake brewing. The crystal is branching out wonderfully	**Berlin (Germany): This is the energy structure of Berlin's drinking water The missing crystal structure concludes to not a good quality in the moment.**	**Thanks: In this experiment the word thanks was stuck on the glass. This resulted in a crystal with a very beautiful, good balanced shape.**

Table 32: Different Type of Water Crystals, Macro Pictures from Berlin, Saijo & Stimulated Water

Maybe, there is a chance to produce water with "healing" qualities, which certain spring water sources of our earth seem to have. This could best done through "multi-purposing" small and micro hydropower stations, or even large hydropower stations as all of them have turbines which could affect water in a more positive way as they do in the moment.

But to reach this scope, much has to be done in order to comprehend the complete nature of water and to find innovative methods to purify water.

[140] Compare *web page of Masaru Emoto*, online under: http://www.masaru-emoto.net [2005.02.02].

5.9 History of Small-Scale Hydro Power in Sri Lanka

The central and south-western parts of Sri Lanka are characterised by heavy and persistent rainfall and a rugged terrain with steeply dissecting and rolling landscape. This geo-climatic condition has led to the formation of a large number of streams, which radiate from the upper reaches of the mountains and merge downstream to form major rivers. Small streams in the upper areas as well as major rivers offer considerable potential for hydroelectric power development.

5.9.1 Irrigation Systems

Historically and traditionally, Sri Lanka has not used water to drive machines. The country's worry with water has been focused strictly on its use for irrigation. There is no proof of hydro power used for agro-industrial applications until the early 20th century when MHP was used to process tea leaves on the plantations in the hill country owned by the British. From the 4th century B.C. to perhaps the 12th century A.D., Sri Lanka developed a tremendous irrigation system which was partly restored in the 19th and 20th centuries, and continues to provide water to farmers, especially in the dry zone, where the countries staple food, rice is grown. Irrigation has been based mainly on storage reservoirs ("Wewa" in sinhala). These were certainly a preparing way for today's large hydropower systems. There were also small village tanks, a unique feature of the hydraulic civilisation in Sri Lanka. It is estimated that about 30,000 have been built in the dry zone, in an area of about 15,000 square miles. A village tank and the fields surrounding it are described as a micro-irrigation ecosystem. The tanks were built on a larger scale starting in the first century A.D. The height of bunds increased from 4.3 m – 8.8 m (14 feet - 29 feet), and the length from half to one mile (805 m -1,609 m). The cultivable area under the tank increased from 30-50 acres to areas of between 500 and 1,000 acres.[141]

5.9.2 Small-Scale Hydropower in the Early Days

According to Gilbert Gilkes database, the first turbine to Sri Lanka, then Ceylon, has been supplied in 1887. It was a Vortex type designed to operate under a head of 19.8 m (65 feet) delivering 11.2 kW.[142]

The Sri Lankan tea industry dates back to 1867, after the destruction of the coffee industry by the coffee rust disease.[143] Micro hydro was almost from the beginning of the tea industry the main source of power for its factories. Many were intentionally located close to streams and rivers to take advantage of the energy potential. Power houses and factories were initially built close together, as power had to be transmitted to the machinery by line shafts and belts. As later DC generators became more readily available the power houses could be sited in some distance downhill from the factory to maximize the potential of useful power. The maximum acceptable distance was between 800 and 1,000 metres due to transmission costs and losses in the 415 volt 3-phase lines, which were usually used. The need for micro hydro grew with the growth of the tea industry. The peak of its popularity as a power source

[141] See also Mendis, DLO, *Hydraulic Civilisations, Irrigation Ecosystems and Modern State*, EOE Pereeira Commemoration Lecture, the Institute of Engineers, Sri Lanka, 1989.

[142] Compare *Gilbert Gilkes and Gordon in Sri Lanka*-a list of hydro plants supplied to Ceylon by Gilbert Gilkes & Co. Ltd. from 1887 – 1960.

[143] Compare *Economic and Environmental impact of Micro-Hydro and Biomass-Based Electricity Generation in the Sri Lanka Tea Plantation Sector*, P. Wijayatunga, K. Dhanapala, University of Moratuwa, 2002.

was between a number of 400 and 600 factories employing such hydro systems. About 100 of those are still running. The latest installation before the increase of interest in the last decade was in 1956. The average plant size was about 75 kW matching the need for much of the year. Additionally required power source could economically be met by installing low speed heavy diesel engines. Nearly all hydro systems were, and still are, run-of-river schemes without storage facilities. On the one hand these have the main disadvantage to be much more vulnerable to seasonal water flow fluctuations but on the other hand the cost of constructing dams for seasonable storage is exorbitant.[144]

In the late 1940s large-scale hydro systems to supply the national grid started to be more and more common. So most of the units gradually went out of use and the advantages of micro hydropower appeared to decrease. At this time energy supply was beyond of demand. Therefore, the tea estates were identified by the government as potential customers of grid electricity. With transformers provided on favourable terms it was aimed to encourage factories to change from micro hydropower to grid electricity. Later, by 1985 only 5% of the initial micro hydro units were still operating.[145]

Switching from micro hydropower to grid electricity made short-term financial sense. "*However, in the late 1970s, tariffs increased when generating costs increased, and generating shortfalls forced CEB to use gas turbines to meet peak demand. Power supplies were also unreliable, often resulting in lost production and lower quality of the tea produced. Not surprisingly, micro-hydro re-emerged as an attractive option, and the Ministry of State Plantation recommended investigating the viability of rehabilitating old micro-hydro schemes and developing new ones. The civil works, which can account for nearly 60 percent of total cost, were found in good repair in many of the old installations. Most rehabilitated schemes were found to have a payback period ranging from two to five years, while new schemes were predicted to have a payback period of five to eight years.*"[146]

5.9.3 The Revival

Even in industrial countries small hydropower was playing a far bigger role in earlier decades than presently. Over 50,000 small-scale waterpower schemes have fallen victim to the concentration process in the electricity industry. That means to let die small hydropower were either the general refuse of grid connection or so low tariffs which were not allowing enough economical room for maintenance or substitute investments.

After a standstill of micro hydro development for almost five decades micro-hydro rehabilitations began in Sri Lanka, initially mostly depending on foreign experts. This renewed interest emerged in the plantation industry in early eighties, the reasons being the world-wide interest in renewable energy and the rising electricity price in Sri Lanka which affected the plantation industry.

In the mid eighties two studies were commissioned by the Sri Lankan government to investigate the feasibility of rehabilitating old small hydro plants in the plantation sector.

One of the studies was funded by the British government's Overseas Development Administration (ODA). The implementation was made by Salford Civil Engineering Ltd. in association with Binny & Partners. The ODA decided to share equally a total cost of £11 million the government of Sri Lanka in order to rehabilitate 140 micro hydropower plants,

[144] According to *Upgrading Micro Hydro in Sri Lanka*, Hislop, D, ITDG Publications, 1986.

[145] According to *Beyond big Dams, A New Approach to Energy Sector and Watershed Planning*, IRN, 1998.

[146] Quotation from ibid.

which was later reduced to 80. *"The ODA money from the would be disbursed as a loan, at a 13 percent annual interest rate, payable over 10 years, mainly to cover the British consultancy services – about 25 percent of the total cost – and electro-mechanical equipment. Included in the mechanical equipment, which by contract had to be provided by the UK, were switchboards of the type that had been manufactured in Sri Lanka for many years."*[147]

Both the use of British equipment and the involvement of a disproportionately high level of foreign employees for project implementation led to excessive project development costs. Furthermore, the consultants appeared to have no knowledge of the technical ability available in the country. Maybe that was the reason why only eight hydro schemes could met the criteria of financial viability. Additionally inflation had raised costs by almost 50% which led the government of Sri Lanka not to provide its share of the money.[148]

The second feasibility study was financed by the Canadian government and implemented by CANSULT in association with a local consulting enterprise, De Croos. It was proposed to set up mini-grids fed by a network of small hydro schemes within the plantation region. So, estates with no hydro resources would benefit from the others having excess hydro capacity.[149]

Unfortunately, both studies did not continue beyond the feasibility phase. Nevertheless, some hydro schemes were rehabilitated in this period. The financial and technical support came from the Integrated Rural Development Project (IRDP) of Nuwara Eliya (funded by the Government of Netherlands). The Chinese Government was also assisting some of these schemes. IRDPs objectives included improvement of income, increased production, environmental protection, employment, and social and community services. In 1982, the Intermediate Technology Development Group (ITDG), an international development NGO began collaborating with the IRDP on a program of rehabilitating micro hydropower units. ITDGs considerable contribution to the rehabilitation was through technology development and improving of the technical skills of Sri Lankan engineers and technicians to enable micro-hydro development in the villages.[150]

Realizing the importance of alternative energy in the future, ITDG South Asia started work on village hydro in 1990.

Unfortunately, Sri Lanka is since 1996 looking at costly non-hydro sources of power. The reason is the long drought in 1996 that prevailed in large hydro reservoir areas and resulted in power cuts or up to six hours a day. The inadequate owner compelled the government- monopoly Ceylon Electricity Board to increase electricity generation, mainly through use of expensive thermal and gas resources. The use of imported fuel caused electricity price increases and unfavourable environmental effects. These developments emphasized the need for alternative energy sources which are environmentally friendly and have the capacity of serving the poor. This is very important in a country where over 50% of the population receive government subsidy.[151]

[147] Quotation from ibid.

[148] Compare "*A Look at Aid Projects*", Perera,L and Munasinghe, C, Hydronet, 1992.

[149] Compare *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999.

[150] Ibid.

[151] Quotation from *Role playing game approach to introduce complex water resources decision making process*, Srikantha Herath, United Nations University, 2002.

6 Status of Small- and Micro Hydropower in Sri Lanka

A widely held perception of hydro power is of billion dollar projects involving construction of huge concrete dams to impound sufficient water in a man-made lake of a capacity such that it will smooth out the seasonal fluctuations in flow of the river(s) that feed it. In some cases massive and controversial projects of this kind were constructed, especially in Africa (dams such as Kariba, Aswan, Volta, Cabora Bassa) which involved flooding hundreds of square kilometres to store cubic kilometres of water. Today, in an era of greater sensitivity to the environment, such projects have tended to give all forms of hydro power a bad name. This is because the huge artificial lakes have had significant negative environmental impact in terms of displaced populations, loss of land and even considerable greenhouse gas production due to rotting vegetation in the lakes. Many of these systems are often not totally sustainable, since the lakes can gradually silt up, eventually to become malarial marshes with greatly reduced capacity for water storage. Having said that, it must also be stressed that no large-scale method of energy production can be entirely without environmental impact, and in many cases large hydro schemes, despite their shortcomings, might be a lot less harmful in general than most other methods of power generation. There is sometimes a danger of double standards from some environmentalists, demanding that clean renewable energy technologies be almost completely benign while we continue to pump harmful emissions into the atmosphere from more and more gas-fired power stations - which seem to be well regarded because they are not quite as bad as coal or oil.

To this day most hydro power capacity consists of large and medium-sized plants of many megawatts each. However there is a growing interest in so-called 'small hydro power' or SHP, defined internationally as any hydro installation rated at less than 10 MW. A sub-set of this is micro-hydro, which covers systems of less than 100 kW.

6.1 Possible Locations for SHP and MHP development in Sri Lanka

According to the United Nations, there are about 20 river basins in the wet zone with an estimated annual run-off of about 26 Million cubic metres and nearly 80 river basins in the dry zone.[152] The three types of possible locations for small-scale hydropower development in Sri Lanka are following:

Irrigation Reservoirs

Small hydro plants can be installed at several large and small irrigation reservoirs. *"The water releases from some of the large reservoirs are controlled are controlled and vary from 5 cumecs[153] to about 40 cumecs, with gross head ranging from 5 metres to nearly 35 metres. As such it is technically feasible to develop hydropower at these reservoirs. In addition to major reservoirs, there is large number of small reservoirs which could also be developed for generation of hydropower."*[154]

[152] Compare *Evaluation of Hydropower Potential of Existing Irrigation Schemes in Sri Lanka*, C. Kariyawasam, UoM, G.M.B. Fernando, CEB, 1988.

[153] Cumecs is an abbreviation for cubic metres per second.

[154] Quotation from ibid.

Irrigation Canals

Several irrigation canals serving the dry zone of the island have been designed with a large number of drop structures. These drop structure locations are potential sites for MHP development.[155]

The potential analysis conducted by the CEB evaluated only 8 MW of small hydropower potential in about 290 irrigation tanks and reservoir sites. Surely, there are much more megawatts to harness, however in low head sites, depending also from irrigation requirements. Besides that, the technology for low head applications has still to be transferred from India or China or even Europe, in order to manufacture them locally and so more economic.

Small Rivers and Streams

Many small streams and rivers and tributaries of large rivers are suitable for small-scale hydro power generation. The potential systems can range from the MHP plant serving for a small village up to the grid connected SHP station.

6.2 Small-Scale Hydropower Background

It is to distinguish between small hydropower systems (SHP), which are mostly located in the plantation areas, where grid-electricity has already reached and off-grid micro hydropower (MHP) systems (commonly referred to in Sri Lanka as Micro Hydro schemes) to serve households in remote areas without national grid connection. As there are more activities in Sri Lanka for MHP, the following information in this chapter is tending more to MHP.

In November 2003 there were 161 MHP stations in operation providing basic electricity needs for 3,687 households in remote villages with a total capacity of 1,622 kW. Even if the power outcome is relatively low this is seen very successful due to remarkable achievements in terms of the number of units and number of households electrified. Another 24 MHP stations of the capacity about 385 kW are not working because of technological, social and planning problems. There are also 26 units under construction having a planned capacity of 238 kW.[156]

Provincial Councils have been playing a very active role to make this technology reach the most remote areas of the country. Sabaragamuwa, Uva and Southern Provincial Councils have promoted the technology by establishing separate ministries for renewable energy and including MHP in their policies. Yearly, they appropriate sums for MHP schemes which makes so far a partly or fully investment in 70 off-grid MHP sites.[157]

6.2.1 Energy Service Delivery (ESD) and Energy for Rural Economic Development (RERED)

The Energy Service Delivery (ESD) project, which was implemented during March 1997 and December 2002 and the Renewable Energy for Rural Economic Development

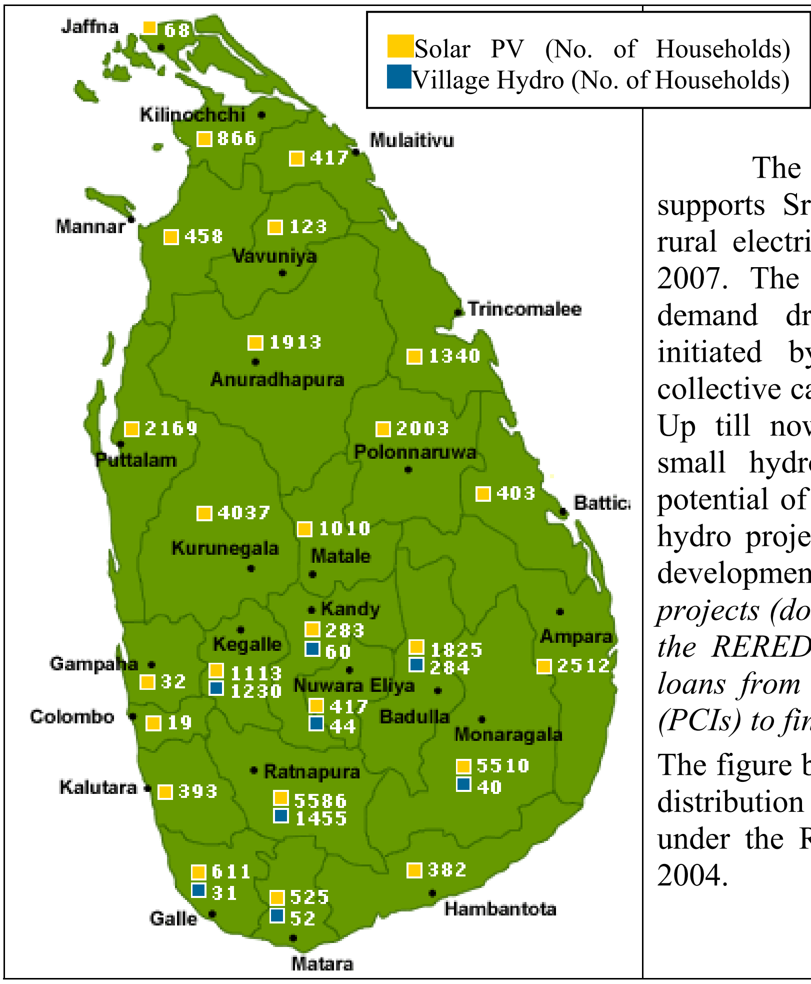
[155] Compare ibid.

[156] Compare *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* J. Gunasekera, Technology Programme Leader ITDG-South Asia, Nov. 2003.

[157] See ibid.

(RERED) project since 2004, both funded by the World Bank, have enabled the wider uptake of MHP for rural electrification through provision of credit, grants and other financial motivations to communities, developers and professionals providing services for industry. These and other various activities by government institutions, NGOs and multilateral donor agencies made MHP moving very fast to provide electricity to remote areas of Sri Lanka with hydro resources.

The ESD Project was instrumental in the installation of 18,600 solar home systems (totally 875 kW), 56 off-grid Village hydro projects (aggregate capacity of 574 kW) benefiting 2,800 homes and 15 grid-connected small hydro projects generating a total of 31 MW. "*Project development and management come under the purview of the Administrative Unit (AU) set up within DFCC Bank, which works closely with the World Bank, government agencies, Ceylon Electricity Board, project developers, participating credit institutions (PCIs), consultants, NGOs and industry associations.*"[158]



The RERED Project actively supports Sri Lanka's vision of expanding rural electricity access to at least 75% by 2007. The project builds further on the demand driven market based approach initiated by the ESD Project and the collective capabilities of many stakeholders. Up till now there are 21 grid-connected small hydro projects with an aggregate potential of 58 MW and 68 off-grid village hydro projects (748 KW) approved and in development. "*Grid-connected mini hydro projects (do not receive grant support under the RERED Project, but they access term loans from participating credit institutions (PCIs) to finance eligible expenditures*".[159]

The figure besides illustrates the geographic distribution of off grid projects approved under the RERED a project in September 2004.

Figure 32: Geographic Distribution of Off-Grid Projects Approved under RERED (2004)[160]

[158] Quotation and source: *Administrative Unit, Renewable Energy for Rural Economic Development Project*, online under: http://www.lanka.net/esdp/whats_new.html# [2004.12.10].

[159] ibid.

[160] ibid.

Project	No. SHP	No. Off Grid MHP
ESD 1997 - 2002	15 (31 MW)	56 (574 kW)
RERED 2004 -	21 (58 MW)	68 (748 kW)

Table 33: Outcome of the ESD and RERED Project

6.2.2 Actual Installed Small-Scale Hydropower Plants

In 1995 was the first successful commissioning of a stand alone grid connected SHP plant with 800 kW of installed capacity. By end 1998, three more SHP plants with a total capacity of approximately 1 MW were connected to the national grid. By end February 2000 the total capacity of grid connected SHP stations was about 12 MW.[161]

In 2003, the CEB was maintaining three small hydro plants (Inginiyagala, Uda Walawe and Nilambe) contributing 20 MW to the national grid whilst private small hydro plants connected to the network system amounted around 37 MW. Further 37 MW of private plants were under construction and Letters of Intents had been issued for another 100 MW.[162]

When additionally the RERED SHP projects are implemented in the next years, another 21 plants having an aggregate potential of 58 MW will be connected to the national grid. But this will take some years. It is yet not clear if these 58 MW were already considered in the CEB Long Term Generation Expansion plan of June 2003 as Letters of Intents. Assuming the ESD projects being already implemented and contributing their potential to the grid, the following estimation can be made by the author:

Generation Type	Number	Total Installed Capacity
Small Hydropower	30-40	100 MW
Micro Hydropower	200-250	~2 MW

Table 34: No. & Installed Capacity of SMH & MHP Stations Estimated by Author (2005)

All together about 30 - 40 small and small hydropower stations with a total installed capacity of about 100 MW contributes to the national electricity network while at least 200 micro hydropower stations with a total installed capacity of about 2 MW serve remote areas in rural Sri Lanka.

6.3 Small and Micro Hydropower Potentials in Sri Lanka

Even if the total potential for small-scale hydropower (up to 5 MW) is around 200 MW, compared with the islands' actual installed capacity (2,000 MW), it offers a viable source of energy to supplement Sri Lanka's electricity demand. Its field is more located in rural areas without access to grid electricity or grid connected industries in the plantation sector, who once abandoned their small-hydro facilities because of CEBs grid expansion activities. Compared with the estimated total SHP potential of 10,000 MW in India, Sri Lanka

[161] Quotation *Grid Connected Small Hydro Power in Sri Lanka*, Dr. Romesh Dias Bandaranaike, International Conference On Accelerating Grid-Based Renewable Energy Power Generation for a Clean Environment, 2000.

[162] Compare *Long Term Generation Expansion Plan*, CEB, 2003.

has about 50 times less SHP like also 50 times less inhabitants (1 billion Indians/ 20 million Sri Lankan).

Estimations concluded, "*that for about 20% of Sri Lanka households (about 640,000 homes), it will not be economic to bring them grid supplied electricity. However, Sri Lanka is rich in renewable resources, such as small-scale hydro, solar, biomass and wind, which could be used to provide power to these isolated communities. These can be community-run systems that offer limited, but reliable supplies of electricity at prices not affected by world fuel market conditions. They generally use technology that can be produced and maintained locally. The main technology used at present is micro-hydro, although other technologically proven options, such as wind-power can also be used. Worldwide interest in small-scale decentralised power sources is likely to make additional options, such solar power and biomass (using specially planted trees) economically viable.*"[163]

Potential Type	Potentials in Sri Lanka
MHP up to 100 kW	41.5 MW (1023 locations)
SHP 100 kW - 5 MW	150 MW (~400 sites)
SHP 5 MW - 10 MW	50 – 100 MW
Total SHP 0 - 10 MW	**About 240 – 290 MW**
Medium Hydropower 10 - 25 MW	**200 – 250 MW**

Table 35: Summary of Sri Lanka's Recorded Small-Scale Hydropower Potentials (2005)

This data is basing on the following sources:

- Recommendations made by the ITDG cite 137 old SHP plants and additionally 120 potential new sites having a total exploitable potential of about 100 MW to feed the national grid. [164] and additionally,
- an overall potential for Off-Grid Micro Hydro schemes of about 41.5 MW with a number of 1,023 sites.[165]
- Furthermore, there is a potential of about 50 MW surveyed by the CEB in the Electricity Master Plan of 1988 not included in the mentioned study of ITDG.
- This makes a total amount of small-scale hydropower (up to 5 MW) potentials of about 200 MW.[166]
- Additionally, another source claims that there is a total potential of about 250 – 300 MW SHP (up to 10 MW) which could be harnessed and a further 200-250 MW of financially viable sites between 10 MW and 25 MW [167]

Figure 33: Sources used for the Potential Estimations

[163] See *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

[164] Compare *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999.

[165] Compare *Assessment of Off-Grid Micro Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 2000 and *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

[166] Assumed by author.

[167] *Grid Connected Small Hydro Power in Sri Lanka*, Dr. Romesh Dias Bandaranaike, International Conference On Accelerating Grid-Based Renewable Energy Power Generation for a Clean Environment, 2000.

A more detailed presentation of the potential assessments is given in chapter 6.6 on p. 92.

6.4 The Need for Village Hydro Schemes

As approximately 65% of the Sri Lankan population have access to (grid) electricity and it is estimated that about 80% could reasonably be served by grid extension there are still enough off-grid regions in Sri Lanka to be electrified. Those having no access are among the 70% living in rural areas of the country's total population of 19.9 million. Two factors influence the ability of the poor to obtain electricity: the grid extension and the capacity of the people to bear the costs of connection and pay consumption. The main energy source for lightning in rural homes is kerosene oil, although it has been found unsafe. Domestic accidents resulting from its use is a common phenomenon in rural areas, while kerosene accounts for the highest expenditure in the household energy budget. People without electricity supply use on the one hand car batteries for operating radio cassette players and televisions and on the other hand dry batteries for torches and radios.

Micro hydropower has been used considerably to meet the energy needs of most Sri Lankan remote villages possessing hydro resources. The feasibility of this renewable technology was demonstrated in Sri Lanka the first time in the year 1991 by ITDG, a NGO. By engineering a formal society, the Electricity Consumer Societies (ECS), consisting of prospective village electricity consumers, including women, the MHP stations could be completely managed by the communities of the villages. These ECS deal with the main tasks such as operation, maintenance, collection of the tariff and the responsibilities like overall management of the project, discipline and compliance of the membership to the standards and procedures which are set up by the society leadership. This new ECS approach has enabled a rapid uptake of micro hydro in Sri Lanka. With the funds of ECSs developed through regular tariffs paid monthly (up to US$6) to the Society by beneficiaries, ECSs ventured out into other village development activities as well. These include road construction, aiding at village funerals in member families and loans for income generation.

The NGO ITDG created an enabling environment for the wider uptake of the off-grid rural electrification option through MHP. The interventions were:

- Building capacity at local manufacturer/supplier level, NGO, provincial council and national level,
- project designing, implementing and evaluation, and
- creation of awareness at policy formulation level.

Table 36: Interventions by the ITDG to Create an Enabling Environment for MHP[168]

[168] Compare *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* J. Gunasekera, Technology Programme Leader ITDG-South Asia, Nov. 2003.

6.5 The Strategies to Introduce Small- and Micro Hydropower

6.5.1 The Differing Objectives of MHP Development

MHP plants can achieve a wide range of quite different objectives. Much confusion arises when all MHP plants are treated as a homogenous category. It is therefore important to judge the viability of each MHP investment in terms of a specific objective. Like in the formulation of government or donor policy, it is important not to expect MHP to achieve many, often conflicting, objectives. For example, it is not possible to provide electricity to very poor people in remote areas through MHP and make a return on capital similar to that achieved in Europe's capital markets.[169]

Nevertheless, MHP has been accepted as a proven approach to electrify off-grid communities in order to develop them in a sustainable way. The key strategies hereby are:

- **Investment of sufficient time and other resources on Research and Development (R&D),**
- **pilot testing,**
- **technology Transfer,**
- **high community participation,**
- **building of capacities at different levels to facilitate effective adaptation of technology, and**
- **creation of an enabling environment for wider uptake.**

Table 37: Key Strategies Used in the Micro Hydropower Sector[170]

6.5.2 Research and Development

In late 90s ITDG was involved in rehabilitating some abandoned MHP stations belonging to Estate companies. This made ITDG to gain lots of experience and knowledge not only in the laboratory as usual but directly in practice. This created confidence on the validity of the technologies.

6.5.3 Pilot Testing

After gaining knowledge and experiences in the R&D the technology was checked for its viability at community level as there is a different in these off-grid MHP projects compared with the well established management system in the estate sector. Key factors governing the pilot testing process were:

- **making the technology simple to suit the rural set up,**
- **transfer the basic minimum technological know-how for operations,**
- **maintenance and troubleshooting,**
- **creation of local capacity for technological service provision,**
- **setting up a system within the community for the system's management,**
- **making the system affordable.**

Table 38: Key Factors Governing the Pilot Testing Process[171]

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[169] Compare *Best practices for sustainable development of micro hydro power in developing countries*, ITDG 2000, p. 3f.

[170] Compare *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* J. Gunasekera, Technology Programme Leader ITDG-South Asia, Nov. 2003.

The work demonstrates that MHP in off-grid regions with low electricity demand is a viable option.

6.5.4 Technology Transfer

It is necessary to understand the importance of the hardware and engineering skills in the success of MHP development. There is a need to get the technology right, and develop the technical skills necessary to build, install, operate and maintain the equipment and the associated civil works. While much work was done on manuals, standards, training, and correcting faulty engineering and associated errors, the physical assets remain an important cause for failure. A study on the functional status of the state of existing MHP plants in Nepal[172] resulted in some 30% of the installations were not in operation, due in part to:

- **Poor site selection, inaccurate/inadequate surveys, wrong size, poor installation, faulty equipment;**
- **Plants affected by floods and land slides;**
- **Poor estimation of hydrology, in part due to surveys being conducted in the rainy season**
- **Uneconomic canal length, bad canal design;**
- **Neglects of civil works;**
- **Inability of owners to replace generators after breakdown, and**
- **Wrong estimation of raw materials, of demand, of end-use possibilities, oversized plants, over estimation of tariff collection, inappropriate rates, ignorance of competition with diesel.[173]**

Table 39: Technical Reasons of Malfunction of Small Hydropower Systems

It is also to mention, that there are still a number of unresolved technical issues, like for instance the trade-off between the quality (and therefore the cost) of the civil works and the resulting costs of operation and maintenance. Low cost civil works tend to be washed away by the monsoon rains and have to be substantially repaired each year. It is not yet clear where the optimum balance between these two types of cost lies.

The approach taken by ITDG highlights important dimensions of a successful technology transfer methodology.

"Community involvement in as many aspects as possible, starting from selections of locations, conducting feasibility studies, designing of the micro hydro systems, construction, installation and commissioning of the power plant has made great awareness among the user communities on the technological aspects of the system. The structured training on operations and maintenance of the units for selected members of Electricity Consumer Society increases the technology knowledge base at the village level which has strengthened the sustainability

[171] ibid.

[172] Earth Consult (P.) Ltd, *A report of Random Sample to Determine Actual Status of Private Micro Hydro Power Plants in Nepal*, ICIMOD-ITDG Nepal, 1998.

[173] See also *Scaling-up Micro Hydro, Lessons from Nepal, and a few Notes on Solar Home Systems*, Wolfgang Mostert, Village Power 98 Conference, NREL/World Bank, Washington October 6-8, 1998.

of the technology. These training programmes were carried out by the micro hydro technician who provides the electrical and mechanical equipment and after sales services; thus it became an effective and cost saving approach."[174]

6.5.5 Institutional Strengthening

To create and strengthen an institutional set up within the village for the management of the MHP station is a significant aspect of the project. For this reason the concept of the ECS was introduced. The ECS deals with the main tasks such as operation, maintenance, collection of the tariff and the responsibilities like overall management of the project, discipline and compliance of the membership to the standards and procedures which are set up by the society leadership. Again viability was proven, that communities are capable and willing to take the responsibility of managing these systems providing their basic needs.

6.5.6 Capacity Building in Sectors

As all hydropower installations in plantations were manufactured in foreign countries, the technical capacity was not high. In order to improve this situation, ITDG built up capacity of six local mechanical workshops to produce hydro turbines and the related components with local materials, and also to manufacture and adapt equipment from existing designs. Advantages of this decentralised workshop system is its accompanying after sales service and trouble shooting activity. Following, the technical support employees were located relatively close to the targets and were bringing out the needed backward linkage support to the MHP systems at village level.

Another important step was the carrying out of training programmes by the ITDG for all kind of technicians. They were aiming mainly local engineers having the necessary technical background to design and develop MHP units. ITDG employees were also grouped together with engineering faculties and other freelance consultants for other technical services like the selection of the site, feasibility studies and design details associated with construction and organizing required finances through local banks and other lending institutions.

6.5.7 Creating an Enabling Environment

The change of the policy level in Sri Lanka was very significant in the Village Hydro Project. ITDG achieved it through different strategies aiming to influence the provincial councils to introduce MHP into their rural electrification plans. To convince them awareness creating workshops and field visits were done, newspaper articles were written, radio programmes were broadcasted and also collaborative pilot projects were created. As an encouraging result after the initial scepticism Sabaragamuwa, Uva and Southern Provincial Councils have promoted the technology by establishing separate ministries for renewable energy and including MHP in their policies.

As the World Bank was preparing its credit programme in 1994 the focus was only on solar home systems for rural electrification. After creating awareness including site visits MHP for off-grid electrification was included in the Energy Services Delivery Project (ESD). This paved the way forward for wider uptake of the MHP technology. Under the ESD project ITDG carried out many tasks using the experience and knowledge obtained in prior work. Tasks were for example the carrying out the Village Hydro potentials, building technical and

[174] Quotation from ibid.

social mobilising capacities of local NGOs and establishing a sustainable financing mechanism in the Sabaragamuwa province. The following potential study covering 10 districts of the Uva, Central, Sabaragamuwa and Southern provinces provided an information base for potential developers which were funded by the ESD project.

Essential and significant factors of success in designing of technology based development intervention are following:

- **Investment on R&D,**
- **involving the communities in the technology development process,**
- **integrating the social and economical context into intervention,**
- **influencing effectively and continuous monitoring and**
- **evaluation and redesigning of the approaches and strategies.**

Table 40: Essential Factors of Success in Designing of Technology Based Development Intervention[175]

6.5.8 Foregone Conclusion-Challenges for the Future

Because of the rapid phase of MHP adaptation and some of the recent policy changes in Sri Lanka's energy sector has resulted in following concerns hindering the progress of the concept, related to

- **the quality of the equipment and services provided by the handful of MHP technicians,**
- **limited knowledge of the MHP technicians and local manufacturers,**
- **the legal positions of community based rural electrification systems,**
- **gaps in the further R&D, and**
- **poor networking among the sector's significant stakeholders.**

Table 41: Concerns Hindering the Progress of the MHP Concept[176]

Due to monetary benefits NGOs, private sector companies and individuals were attracted to the MHP business because the ESD project and the Global Environment Facility project (funded by the UNDP) made credits and grants available. These groups were employed to help rural communities to identify potential villages, carry out feasibility studies and prepare project plans etc. On the one hand, the ESD project was financing necessary training programmes for these groups to improve their knowledge, on the other hand the project made credit facilities to rural communities available and provided grants calculated on the generated capacity of the MHP system. During its period of implementation from March 1997 – December 2002 the ESD project *"has contributed to 56 off grid micro hydro power plants with a total capacity of 574 kW providing electricity for 2,800 households. This is seen*

[175] Compare *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* J. Gunasekera, Technology Programme Leader ITDG-South Asia, Nov. 2003.

[176] The contents of this chapter are mainly taken from *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* ITDG-South Asia, Nov. 2003 as long as no other source is given.

as one of the most successful projects of its nature due to its remarkable achievements in terms of the number of units and number of households connected."[177]

Because of these credits and grants a big demand was created and that overloaded the existing handful of suppliers with many jobs. As a result the quality of the supplied equipment deteriorated and delays in meeting the time frames which were agreed between communities and suppliers were also recorded resulting in frustration and a wrong impression among the rural communities on the technology.

Therefore, ITDG tried to find out what has gone wrong and what is necessary to bring back the technology's appreciation. For this reason four workshops were organized at different stakeholder level to understand the present issues of the MHP sector and to find out what measures are required to address those issues. The stakeholder groups were off-grid MHP consumers, MHP developers (NGOs, private companies and individuals), equipment manufacturers and suppliers and also provincial council officers. The identified issues are resumed as follows:

- **Quality of services**
- **Technology transfer**
- **Technical knowledge of suppliers**
- **New developments**
- **Networking**

Table 42: Present Issues of the Micro Hydropower Sector

Quality of Services

The locally manufactured components had a considerable deterioration in quality resulting in output decreasing compared to designed capacities and frequent major break downs within very short periods of commissioning. Same manufacturers had supplied and installed systems earlier which are running more then 10 years without any failure. Also due to undertaking over work delays in project implementation plans, which were agreed by many parties including communities, banks and provincial councils are recorded. These delays caused lots of other problems between these partners. For example one community has been paying the instalments and the credit interest for more than one year without enjoying electricity. The original concept was the repay with the money they spent on kerosene, but the delay caused duplicated costs.

On the one hand a quality aspect of the services is the reaction time of suppliers to break downs and maintenance work of MHP units, which took in some cases some month. On the other hand, from the manufacturer's point of view, good quality imported items for speedy and quality jobs are not available in the market.

While during the pilot period the quality supervision through the ITDG was sufficient the present regulatory function seems not effective enough.

[177] Quotation from ibid.

Technology Transfer to the Community

The technology transfer to the community is one of the most important features experienced by ITDG. One key strategy is the involvement of the community at all stages, beginning in the feasibility study up to electro-mechanical installations in order to build up their technical know-how of the system whilst another strategy is the structured technical training. The identification of electricians and mechanics in the vicinity of the village in order to be trained on trouble shooting light repairs is also important. In all these processes the supplier plays the significant role of the trainer. But in the present rapid process communities do not adequately attend to routine maintenance resulting in permanent damages to the system which costs lots of time and money. Communities have also poor technical knowledge making them vulnerable to break downs and dependent on the supplier who lives away from the villages and who will take months to attend. On the one hand they are kept in darkness and on the other hand it is prevented for others to adopt the technology.

Suppliers Technical Knowledge

Successful setting up of a SHP system mainly depends on the supplier. Once the manufacturer has received the basic design, they carry out the installation and commission together with the community. Therefore a great part of the success of the system depends on the manufacturer’s knowledge.

Technology Transfer from Nepal, India and China

The technology which was introduced in the early nineties in Sri Lanka remains still the same without any further developments. E.g. the mould sets still used by manufacturers for casting the turbine blades are brought to the island from Nepal in 1992 whilst in Nepal had been considerable improvements in the blade designs. These improvements have not yet come to Sri Lanka. On the one hand there are no further technology developments in then country and on the other hand new developments in other countries such as Nepal, India and China are not transferred to Sri Lanka.

Proposals for Technology Transfer Acquired in Sri Lanka through Interviews

According to Dr. Nishantha there is lack in new developments in the turbine manufacturing technology in order to use new type of turbines. Remaining components of a hydropower scheme like turbine housings, generators, controls or switchgear are already manufactured successfully in Sri Lanka or imported from India, Nepal or China.[178]

Technology transfer is especially in the low head hydropower sector required in order to harness numerous low head sites of the islands tremendous irrigation system.[179] Mr Harsha (the Energy Conservation Fund) emphasized the need for low head turbines, like e.g. Cross Flow turbines below 30 m in order to feed the national electricity grid. Designs between 30 m and 100 m are already manufactured lo [180]

[178] Interview with Dr. Nishantha Nanayakkara, Head of the Small Power Developers Association in Sri Lanka, 11.2004.

[179] According to Mendis it is estimated that about 30000 water storage reservoirs have been built in the dry zone, in an area of about 15000 square miles.

[180] Mr Harsha, Energy Conservation Fund, Sri Lanka, 25.11.2004.

According to Mr Harsha, CEB welcomes every kind of plant supplying power to Sri Lanka's electricity network. The problem with decentralized micro-systems hereby is the inability of communication with these systems. There is no prediction and therefore no control about the next month's power output fed in the national grid. CEB prefers centrally controlled power plants like e.g., hired thermal plants. This kind of power generation has the ability to be turned on or off when desired.

He claims also there is need for new MHP turbine technology up to 10 kW, as here is the most potential in terms of the number existing in Sri Lanka. The costs should amount maximum about US$400 either produced in Sri Lanka or imported from Asia or even Europe. From his point of view technology transfer could be in form of manufacturing and utilising the new type of turbines from Europe in Sri Lanka and even exporting them back to Europe or Canada as manpower- and production costs are low in Sri Lanka.[181]

Networking

The successful take off and sustainability of the technology is affected by effective networking between important stakeholders of the SHP and MHP technology. Presently, linkages between the manufacturers, importers of electro-mechanical components, researchers and design engineers seem to be very weak. Effective communication between these groups will facilitate identifying requirement of one part to the other, issues faced by each stakeholder group and adhering to standards and practices among different parties.

The network within the manufacturers is important in order to share the special expertise each individual has in designing and manufacturing of particular components of the hydropower system. It is also important to maintain good and uniform quality standards and prices among them.

6.6 Different Assessment Surveys Carried Out so far

Aim of this present report is to support widespread development of Sri Lanka's small hydro resources. That results in a starting point for hydro power developers to identify potential and lucrative sites for further development. For this reason the engineering of a comprehensive database on small-scale hydro sites and their exploitable potential is very important.

Such a data base is already prepared by ITDG, Sri Lanka. *"The direct output of the study is a computerised database on small-scale hydro power sites giving the site location, catchment area, estimated average daily flow, head and the exploitable power potential."*[182] Studies drawn up in the past have provided some valuable information for such a database. The list below presents the details of the references and resource database reviewed and used in the present study.

- *Feasibility Study for the Rehabilitation of Mini Hydro Stations,* Cansult Ltd. 1984. (referred to hereafter as CANSULT study)
- *Sri Lanka Mini Hydro Rehabilitation Project,* Salford Civil Engineering Ltd. In association with Binnie & Partners. The project is carried out under assignment by the Overseas Development Administration (ODA), 1986.

[181] ibid.

[182] Quotation from *"An Assessment of the Small Hydro Potential in Sri Lanka"*, S. Fernando, ITDG, Sri Lanka, 1999, p. 2.

(referred to hereafter as the ODA study)

- *Electricity Master Plan* Study*,* CEB, 1988.
- *An Assessment of the Small Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 1999. (referred to hereafter as the Small hydro study)
- Grid connected Small Hydro Estimations by Private Developers, Dr. Romesh Dias Bandaranaike, 2000.
- *An Assessment of Off-Grid Micro Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 2000. (referred to hereafter as the Micro hydro study)

6.6.1 The CANSULT and ODA Study

The CANSULT study has examined about forty sites for rehabilitation and their feasibility. It presents the technical details in respect of only nineteen sites which were selected for detailed study. Anyway, the potentials for reactivating old schemes are recorded in the Small hydro study from 1999 including the data from the CANSULT study. For this reason the CANSULT study is not considered anymore in this paper. The ODA study was very much a feasibility report which was concerning eight selected small hydro sites and revealed very little about hundreds of other old hydro sites.[183]

6.6.2 CEBs Electricity Master Plan Study

The Electricity Master Plan Study conducted by the CEB in 1988 aimed partially to examine the feasibility of rehabilitating SHP plants in the plantation sector. In the early 1970s, the government had nationalised the plantations. At that time, all large plantations were run by two government corporations. While the study revealed that there is potential for:

- development of new sites;
- harnessing the head from irrigation canals, tanks and reservoirs; and
- reactivation, up-gradation or extension of existing sites.

the study did not result in any sustained programme to develop the SHP sector in Sri Lanka. It was estimated that 30 MW of small hydro potential exists in about 60 undeveloped sites while a further 8 MW in about 290 irrigation tanks and reservoir sites. Another 50 MW of small hydro potential could have been tapped in 140 sites.[184]

There are certainly more potentials than 8 MW in Sri Lanka's tremendous irrigation system which are not considered in this study.

6.6.3 The Small Hydropower Study for the Plantation Sector

It is estimated that more than 350 micro-hydro stations (originally engineered by colonial planters to generate electricity and motive power for their plantation industries) had been in operation in the early part of the 20th century. *An Assessment of the Small Hydro Potential in Sri Lanka* written by Sunith Fernando in 1999 *"presents a preliminary assessment of the small hydro potential in Sri Lanka, focussing largely on the plantation sector. It is based on a two-year research study conducted by the Sri Lanka Country Office of*

[183] Compare ibid. p. 21.

[184] Compare *Master plan for electricity supply for Sri Lanka*, CEB, Sri Lanka, 1988.

the Intermediate Technology Development Group."[185] Small hydro is meant here to include the full range of capacities up to about 5 MW which is the largest capacity surveyed during *the Small hydro study*

According to Sunith Fernando, there is a total estimated small hydro potential of 97.4 MW in Sri Lanka. *"This estimate excludes the small hydro potential of nearly 50 MW identified by the Electricity Master Plan Study conducted by CEB in 1988. As highlighted earlier, the present study cannot be considered as an exhaustive one that has covered all the sites in the country. In particular, the study has not been able to cover extensively the potential sites in the head range of below 30 m.*[186] *The exploitable power potential has been estimated in the present study on the basis of the ADF*[187] *which may not necessarily be the optimum design flow for the particular site. Taking all this into account, it could safely be assumed that the total exploitable small hydro potential in Sri Lanka might be in the range of 170 MW-180 MW.*[188]

The total number of the surveyed sites is 257. These can be grouped in Old Estate (137), New Estate (71) and Non Estate sites (49). It should be emphasised, that the Small hydro study is focussing largely on the plantation sector.

Site Classification	Number of Sites	Utilised Potential (MW)	Exploitable potential		Highest Site Capacity (kW)	Lowest Site Capacity (kW)
			MW	% of the total		
Old estate sites	137	6,1	23,668	24,4	1,665	5
New estate sites	71	-	20,723	21,2	1,127	8
Non estate sites	49	-	53,016	54,4	5,192	44
Total	257		97,407	100		

Table 43: Distribution of all SHP Potential Sites by Classification & Capacity[189]

Old Estate Sites contribute with 137 sites 53.3% to the total number. At this locations, there are still or had been hydro plants in the past with a total exploitable potential of about 23 MW including sites belonging to the three classification abandoned, not in operation and in operation. The original old estate installations, in some cases were designed to provide less power than is now needed.

The contribution of 71 surveyed New Estate Sites to the exploitable overall potential is with 20.7 MW 21.2%. These are new locations found within boundaries of the investigated old estate sites in the plantation sector.

Altogether 49 Non Estate Sites were surveyed having a total exploitable potential of 53 MW making 54.4% of the total. These sites are situated outside an estate, mostly on state land.

[185] Quotation from ibid.
[186] Low head potentials in off-grid regions are recorded in the Micro hydro study on page 22
[187] ADF is an abbreviation for **A**verage **D**aily **F**low
[188] Quotation from ibid. p. 31.
[189] Adapted from ibid, p. 27.

"Of the estimated potential of 97 MW, nearly 45 MW is found in the estate sector which could generate (assuming a plant factor of ~ 50%) about 200 GWh annually. Full development of this small hydro potential could generate annual revenue of Rs.600 million within the estate sector assuming an average electricity purchase price of Rs.3.00 per kWh. Assuming an investment of the order of Rs.90,000 (~ US$1,200) per kilowatt installed capacity, the total investment in this sector would be about Rs.4,050 million (~ US$54million). This leads to a simple pay-back period of about 6.7 years."[190]

Therefore, small hydropower seem to be a financially attractive and large enough investment chance for firms who wish to diversify income generating activities within the plantation sector. Nonetheless, investment in the small hydropower development in the estate sector is yet to gain momentum.

The following two figures show the distribution of all sites by the estimated exploitable small hydro potential in respect of two ranges of capacity, 0 – 500 kW and 500 kW – 4,000 kW. In 209 sites there is the estimated site potential less than 500 kW within 22% of these sites have less than 50 kW and 25% lie between 50 kW and 100 kW. Nearly 70% (48) of the sites in the range from 500 kW to 4000 kW have capacities between 500 kW and 1,500 kW.[191]

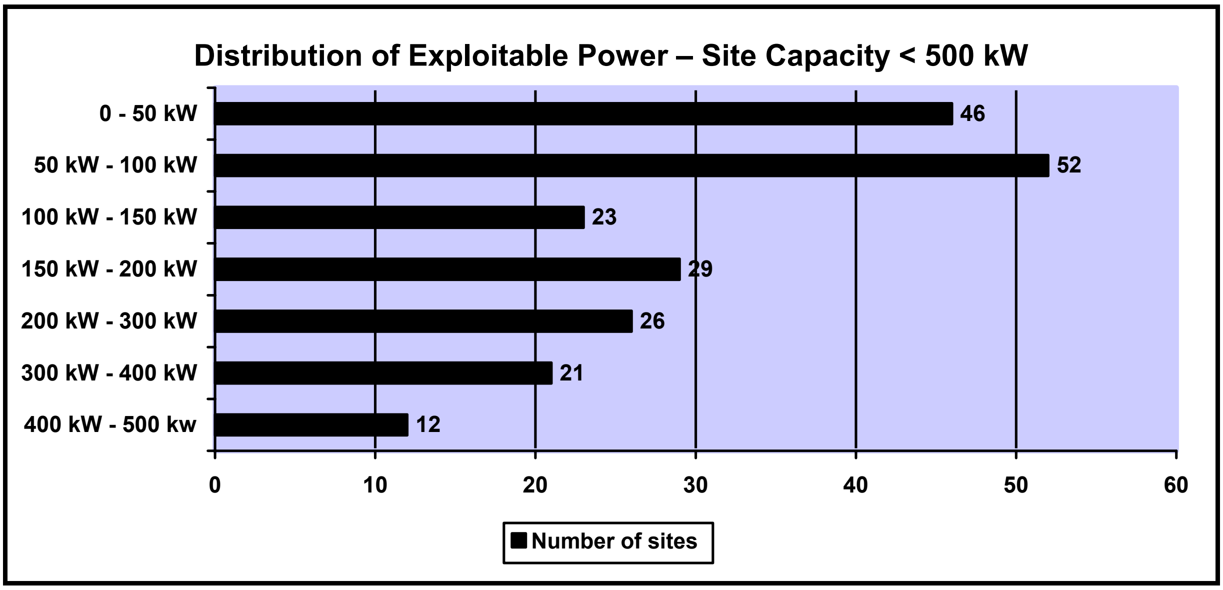

Figure 34: Distribution of Exploitable Power – Site Capacity < 500 kW

[190] Quotation from *An Assessment of the Small Hydro Potential in Sri Lanka*, S. Fernando, ITDG, Sri Lanka, 1999, p. 31.

[191] All figures and information in this chapter are adapted from ibid.

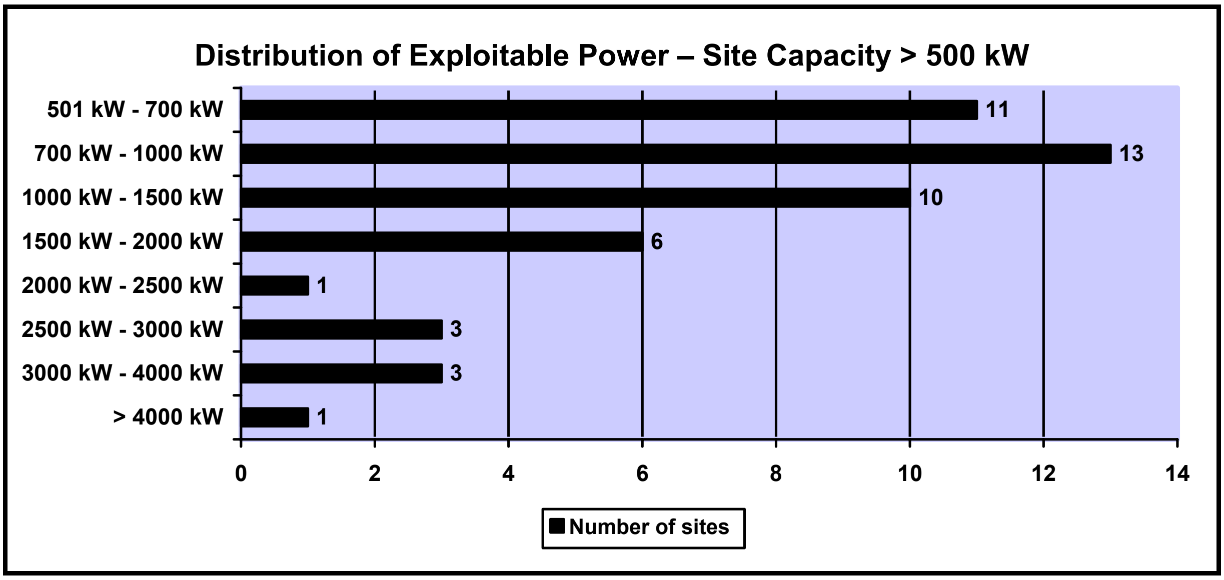

Figure 35: Distribution of Exploitable Power – Site Capacity > 500 kW

All the small hydro sites found in the small hydro study are in the wet zone, having the most number of sites in the district of Nuwara Eliya (103), Ratnapura (49), Kandy (43), Kegalle (29) and Badulla with 29 sites. The district wide distribution of the small hydro potential is shown in the following figure.

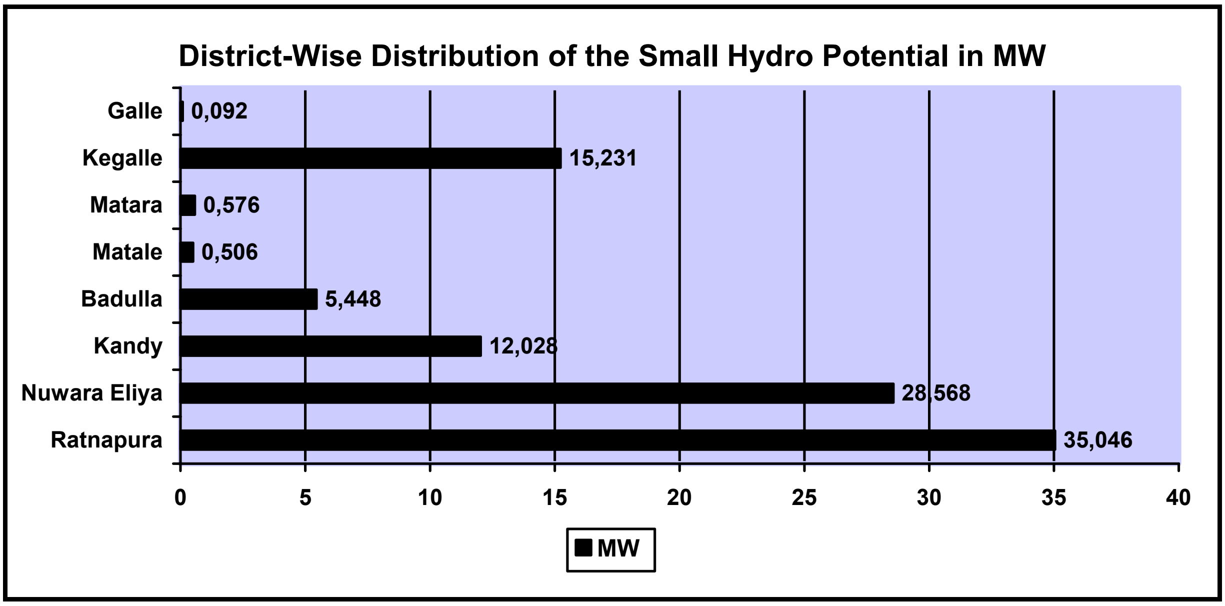

Figure 36: District-Wise Distribution of the Small Hydro Potential in MW

6.6.4 Grid Connected Small Hydropower Estimations by Private Developers

There is also a paper which was presented at the International Conference On Accelerating Grid-Based Renewable Energy Power Generation for a Clean Environment in 2000. This paper was prepared by Dr. Romesh Dias Bandaranaike, who is the president of the Grid-Connected Small Power Developers Association.

"Sri Lanka has a relatively high potential for SHP, compared with the present installed capacity of its electric utility grid. It has been estimated that there are 250-300 MW of financially viable SHP sites up to a capacity of 10 MW and a further 200-250 MW of financially viable sites between 10 MW and 25 MW. This total potential of around 500 MW is over 30% of the installed grid capacity in the country as at end-1999."[192]

It is not clear, where these estimations come from. Unfortunately, attempts to contact to the Dr. Romesh Dias Bandaranaike were not successful. Nevertheless, these estimations were also included in the total estimated SHP potential in Sri Lanka as they are not contradictory with other surveys. The importance of this paper is not to assess exactly all potential sites with accurate details. This is not possible due to vague potential estimations through desk studies in the different assessment studies. The main objective is the creation of awareness in different sectors that there are enough SHP potentials waiting to be exploited.

6.6.5 Off Grid Micro Hydro Study

In 2000, ITDG carried out this off-grid micro hydro potential assessment for the ESD project. The results show an estimated meteorological potential of about 36 MW in 853 sites in 10 districts of the Uva, Central, Sabaragamuwa and Southern provinces. On the basis of 200 W per household this capacity is sufficient to meet the basic power requirements for nearly 180,000 households.

Unexploited off-grid MHP potentials are still waiting to be used especially in the wet area of the island. They can contribute well to the nationwide electrification rate, as in a typical off-grid MHP system only 100 W – 200 W of electrical power is given to each household. This is enough to operate either 3-4 lamps or a television and radio set. Even if the power outcome is relatively low this is seen very successful due to remarkable achievements in terms of the number of units and households electrified. There were for example 161 micro hydro power stations with a total capacity of 1622 kW in operation providing basic electricity needs of 3,687 households in remote villages. While in 2000 the monthly tariff was about Rs.100 (US$1.3) per household charged to meet O&M expenses this tariff increased to Rs.300- 600 (US$3-6) in ESD off-grid projects. The owner and manager of such scheme is the Electricity Consumer Society (ECS) where the consisting members are from the beneficiary families. The ECS deals with the main tasks such as operation, maintenance, collection of the tariff and the responsibilities like overall management of the project, discipline and compliance of the membership to the standards and procedures which are set up by the society leadership.[193]

The table on the next page shows the accelerated growth in the past years of MHP schemes nationwide.

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[192] Quotation *Grid Connected Small Hydro Power in Sri Lanka*, Dr. Romesh Dias Bandaranaike, International Conference On Accelerating Grid-Based Renewable Energy Power Generation for a Clean Environment, 2000.

[193] See *World Bank Support for Sustainable Energy in Sri Lanka*, online under: http://www.energyservices.lk [2005.11.17], more information on costs is in section 6.9.

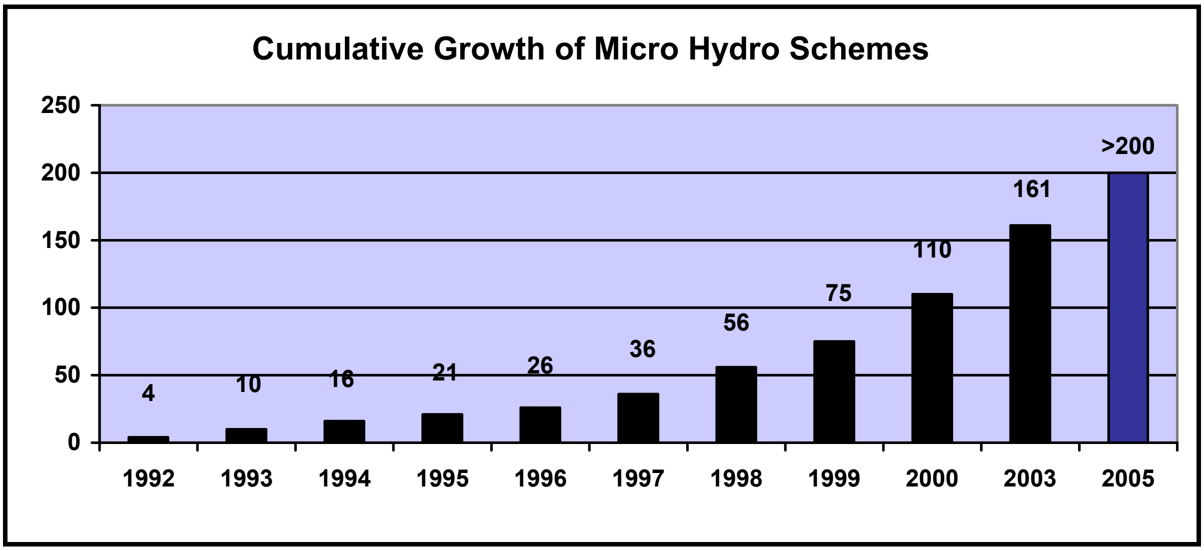

Figure 37: Cumulative Growth of Micro Hydro Schemes since 1992[194]

The number of more than 200 MHP schemes in the year 2005 is assumed by the author, as there is no data available for the year 2004 and 2005. This estimation is based on the addition of the total number of MHP projects implemented in the course of the ESD project. In the year 2003, this is the year of the most actual data, these projects were mostly still in construction.

If Sri Lanka's electricity demand continues with the prevailing expansion factor of 7% annually and Sri Lanka has still no solution for the energy question the energy crisis is not to be solved. For this reason the government authorities should take the implementation of micro hydro power schemes in the form of decentralized energy option into serious consideration.

On the one hand MHP has advantages like significant improvements in education, sanitation, healthcare and the overall standard of living. These benefits are achieved both directly – as in the supply of light - and indirectly - as the time and money that people save is redirected into other projects. On the other hand by reducing the need to cut down trees for firewood and increasing farming efficiency, MHP has additionally a positive effect on the local environment.

According to ITDG the cost for a typical micro-hydro system varies depending on the project. As a guide every installed kW cost around US$1,200. A six kW scheme, which is enough to drive an electric mill and provide light for a community of about 500 people, would cost approximately US$7,200. ITDGs experiences show that community capital in form of "sweat equity" and cash, financial credit and improved income makes these schemes economically viable and sustainable.[195]

The Micro hydro study conducted also by Sunith Fernando (ITDG Sri Lanka), offers important data on about how many off-grid micro hydro potentials are available in Sri Lanka

[194] Source: ITDG Asia & estimation for the year 2005 by author

[195] The information in this chapter 6.6.5 has its source *Assessment of Off-Grid Micro Hydro Potential in Sri Lanka*, Sunith Fernando, ITDG, Sri Lanka, 2000 as long as no other source is given.

and how many of them are worthwhile developing them, considering both the technical feasibility and also the need for energy in non-electrified remote areas.[196]

The largest number of sites (227) is located in Ratnapura making 26% of the total 853 surveyed sites. The next larger percentages are indicated by the districts Badulla (19%), Kegalle (16%) and Kandy with 15%. This is shown in the figure below.

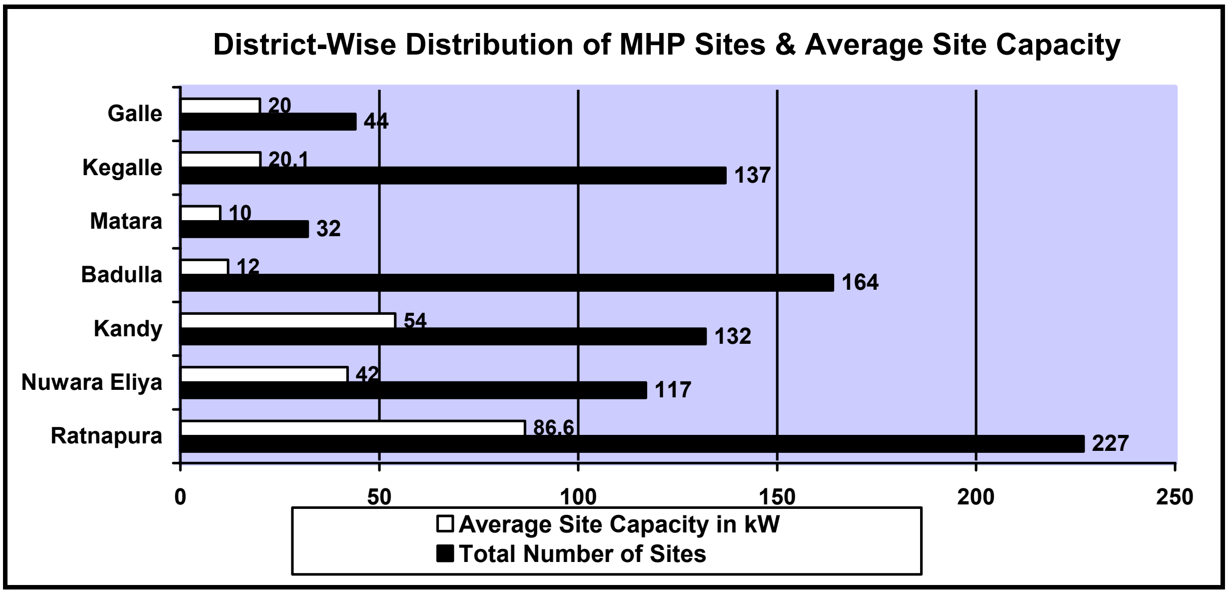

Figure 38: District-Wise Distribution of MHP Sites & Average Site Capacity

Figure 39 above shows comparatively high potential for micro hydro development in Ratnapura, Kandy, Kegalle, Nuwara Eliya and Badulla districts. Furthermore, Ratnapura, Kandy and Nuwara Eliya show high average site capacities while their electrification rate is also high, being 45-70% compared with only 10-20% in other districts. The district-wide richness of water resources are indicated in the bar chart further down. Well-distributed comparatively heavy rainfall in the districts Ratnapura, Badulla, Kegalle and Galle contributes significantly to their high number of potential sites for developing micro hydro schemes. Additionally these districts face the two main wind directions of the year, namely the South-western and the North-eastern monsoons.

[196] Please note that the study is mainly based on the data collected from the desk study, which has been conducted by using topographic maps of the Survey Department. Furthermore, the districts of Matale, Kalutara and Moneragala are not surveyed in this study.

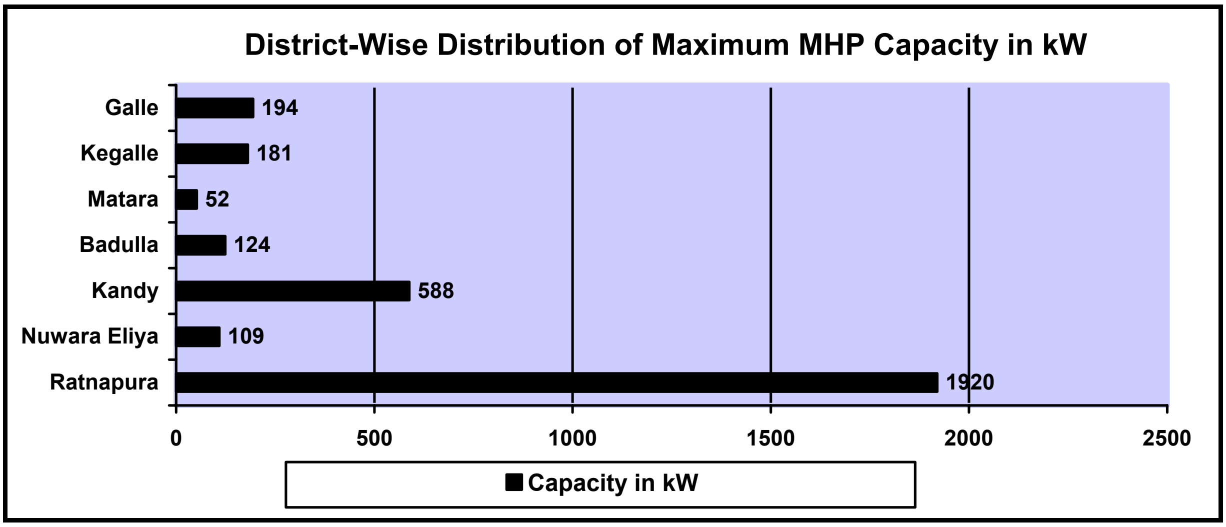

Figure 39: District-Wise Distribution of Maximum MHP Capacity in kW

According to Figure 39 the highest maximum capacity that can be generated is in the Ratnapura district with 1,920 kW.

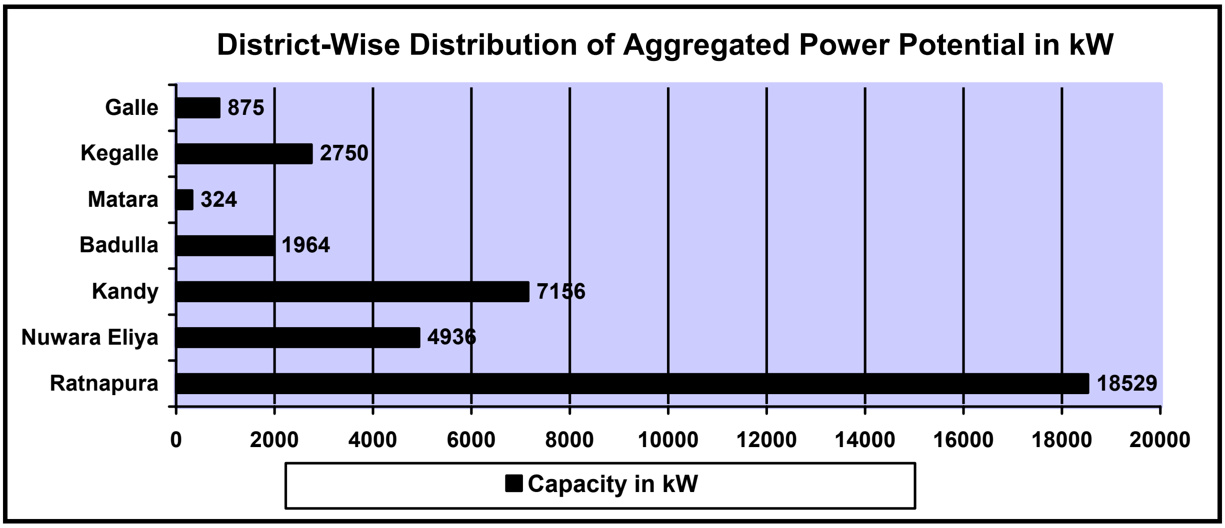

Figure 40: District-Wise Distribution of Aggregated Power Potential in kW

The Micro hydro study revealed that the aggregated potential of 37 MW power could be generated by developing micro hydro schemes in the explored locations. *"The affordability of possessing a micro hydropower project was discussed with some of the respondents during the sample verification. It was revealed that the communities possess the necessary financial capacity to afford the expenses involved in maintaining the micro hydropower generating plant in most cases. The enthusiasm and the consensus of the villages were observed although there were a few reservations due to the inherent limitations of micro hydropower."*[197]

This is together with the main overall conclusion of the Micro hydro study illustrated in the table 44 on the next page.

[197] Quotation from ibid. p. 3.

District	Desk Study Results			From the 10% sample visit		
	Total No. of sites identified from desk study	Aggregated power (kW) potential based on desk study	Average site capacity (kW)	Already electrified	Probable No. of sites without electricity and also technically viable	Probable aggregated power potential (kW)
Galle	44	875	20	20%	35	700
Matara	32	324	10	25%	16	162
Badulla	164	1964	12	39%	91	1090
Nuwara Eliya	117	4936	42	70%	34	1435
Kegalle	137	2750	20.1	33%	92	1843
Kandy	132	7157	54	61%	51	2765
Ratnapura	227	18529	86.6	45%	125	10191
Total	853	36535	-	-	**444**	**18186**

Table 44: Main Outcome of the Micro Hydro Study Conducted by ITDG in 2000

Additionally, there is more actual data about MHP potentials in Sri Lanka. According to *GATS and the threat to community electricity in Sri Lanka, ITDG, May 2004,* the total MHP potentials of the island are 41,490 kW. The outcome of the earlier MHP study is in this 41,5 MW included.

"The results show an estimated meteorological potential of 41,490kW in 1,023 sites in 10 districts of the Uva, Central, Sabaragamuwa and Southern provinces. The past experience shows that this capacity is sufficient to meet the basic power requirements for nearly 190,000 households (on the basis of 200W per household)."[198]

6.6.6 Total Recorded Small-Scale Hydropower Potentials

Potential Type	Potentials in Sri Lanka
MHP up to 100 kW	41,5 MW (1023 locations)
SHP 100 kW - 5 MW	150 MW (400 sites)
SHP 5 MW - 10 MW	50 – 100 MW
Total SHP 0 - 10 MW	**About 240 – 290 MW**
Medium Hydropower 10 - 25 MW	**200 – 250 MW**

Table 45: Summary of Sri Lanka's Estimated Small-Scale Hydropower Potentials (2005)

Please note that the data for SHP is partly from the year 2000. The total national potential would certainly be higher than the present estimate, which is based on the data

[198] Quotation from *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

available to the author. Meanwhile it could also be that some planned SHP plants under the ESD project or even RERED are contributing to the national grid. Therefore, the author estimates the recorded potentials for SHP between 240 MW and 290 MW.

There are certainly still many low head locations (irrigation systems) which are not considered in the previous assessment surveys. Nevertheless, there are enough sites nationwide recorded, especially MHP locations waiting to be harnessed.

6.7 Technology Demonstration, Social Infrastructure or Small Enterprise?

The field of micro hydro is in relation to the motivation of project developers "evolving". Recently the majority of initial MHP installations in Sri Lanka might be said to be the result of a "technology push" in order to test the technical viability and their acceptability. This experience has reduced their cost by improving their reliability and substantial technology. MHP is now a fully developed technology that has been greatly improved by low cost turbine designs and pumps as turbine (PAT), the use of electric motors as generators, electronic load controllers, and the use of plastics in pipe work and penstocks.

The next group of projects is characterised by social objectives. In Sri Lanka many MHP plants have been installed primarily to "improve the quality of life by providing electric light" to the people. In Peru, for instance, the key question for many project developers was "how long will last the plant", rather than "how quickly the capital will be paid back", or "how high is its rate of return".

More recently MHP is seen primarily in terms of securing livelihoods and for the development of small profit-making businesses as the sustainability of grant-based programmes is limited.

"These very different starting points, along with the performance indicators used to evaluate projects, have important implications for what is regarded as a success. Micro hydro as "social infrastructure" uses the approaches and indicators appropriate to schemes for the supply of drinking water, health clinics and schools. Micro hydro as "physical infrastructure" uses the approaches applied to electric power generation more generally, and to such investments as the provision of roads and irrigation systems. Even more recently micro hydro has been seen in terms of small and medium enterprise development, and the role that such enterprises can play in "securing livelihoods"."[199]

Micro hydro developers and financial institutes that they work with have to make choices between these two extremes of social impact and profitability. It is not yet known how to achieve social impacts profitably but surely, many rural people will remain without electricity unless there is some sort of redistribution of income or donates from urban to rural areas. Supporter of MHP are often disappointed that utilities don't take them seriously. Unfortunately MHP often faces unfair competition from a highly subsidised grid, and from subsidised fuels. The scarce resource is not energy, but the capital to make energy accessible, explaining perhaps why they then decide for diesel generators rather than hydro with its higher initial capital cost.

[199] Quotation from *Best practices for sustainable development of micro hydro power in developing countries*, ITDG 2000, p. 3f.

6.8 The Main Forms of Supporting Small-Scale Hydropower

To ensure the success of SHP investments a wide range of actions have to be brought together taking place at various levels: at the micro level of particular investment in a hydro plant at particular location; at the macro level of policy formulation; and in the design and implementation of programmes of financial and other support mechanisms. It was found convenient way to group the many hundreds of tasks that were identified as necessary. The approach extends the idea of *"*Financial Intermediation*"* and considers, according to the ITDG, three additional forms of intermediation, namely

- Technical,
- Social and
- Organisational Intermediation.

Table 46: Forms of Intermediation to Support SHP

Financial Intermediation (sometimes referred to as "financial engineering") involves putting in place all the elements of financial package to built and operate a SHP plant. It covers:[200]

- obtaining subsidies;
- the transaction costs of assembling the equity and securing loans;
- the assurance and assessment of the financial viability of schemes;
- assurance and assessment of financial credibility of borrower;
- the management of guarantees;
- the establishment of collateral("financing conditioning"); and
- the management of loan repayment and dividends to equity holders.

Table 47: Tasks of Financial Intermediation

In this way, projects can also be "bundled" together to cover hole schemes rather than just investment in an individual plant. That makes them attractive to finance agencies, governments, and development banks, and creates the mechanism to convert it into a supply of retail finance (equity finance, and loan finance at the project level).

Technical Intermediation is aiming to improve the technical options by undertaking R and D and importing the know-how and technology "down" through the development of the capacities to supply the necessary goods and services including:

[200] Compare ibid, p. 5.

- site selection;
- system design;
- technology selection and acquisition;
- construction and installation of civil, electro-mechanical and electrical components;
- operation, maintenance and trouble shooting;
- overhaul and refurbishment.

Table 48: Tasks of Technical Intermediation

Organisational Intermediation involves beside the initiation and implementation of the programmes also the lobbying for the policy change, which is required to construct an "environment" of regulation and support in which SHP technology and the various players can thrive. It puts in place the necessary infrastructure, and gets the incentives right to encourage owners, contractors and financiers.

Social Intermediation involves the identification of owners and beneficiaries of projects and the "community development". This is necessary to enable a group of people to acquire the capabilities to take on and run each individual investment project.

6.9 The Economics of Small Hydro in Sri Lanka and its Financial Profitability

Most new SHP installations appear to produce rather expensive electricity as the high in advance capital costs are usually written off over only 7 to 20 years. Nevertheless such systems normally last without major replacement costs for 30 years or more. Therefore, an older hydro site where the capital investment has been written off is cheap to run as the only costs relate to maintenance and replacements from time to time.

"As an example, the unit cost of owning a typical small low head hydro site in the UK might be typically 5 pence/kWh (US 7.5 cents/kWh) during the first ten years while the capital investment is being repaid, but subsequently, because of the low running costs, the unit costs should fall to around one tenth of this level - say 0.5 pence/kWh (US 0.7 cents/kWh). Clearly the output for the first decade will be more costly than power bought from the grid in most cases, although after the capital investment has been paid off, the hydro plant power prices become exceedingly attractive."[201]

Unfortunately the majority of potential users take a short-term view on investment and are put off by the high costs in the initial decade.

6.9.1 Wide Variation in Costs per Kilowatt Installed

Common-sense suggests the economies of scale in the size of each plant make the capital costs vary so much. It should be emphasized that costs for shaft power schemes are relatively low (in average US$965 per installed kW) compared with the installed costs for

[201] Quotation from *small hydro deserves to have its development accelerated in most parts of the world,* Peter Fraenkel, Renewable Energy World, March 1999.

electricity generation schemes (in average US$3,085 per installed kW).[202] This is because schemes designed to provide mechanical power for productive activities such as agro processing are more economic than schemes for which the bulk of the production is to supply electricity for domestic end-uses and services.

In the examples examined below, the capital cost of micro hydro ranges from US$655 in Nepal to US$5,630 in Peru per installed kilowatt.

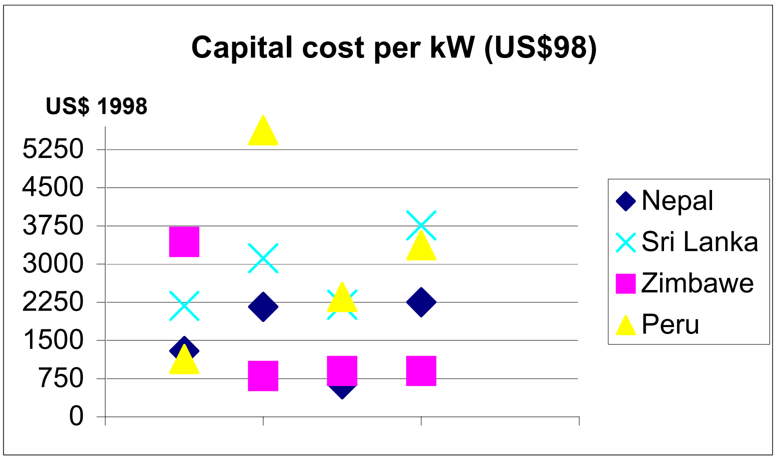

Figure 41: Capital Cost per Installed kW in Different Countries[203]

It is also observed, that the cost per installed kW is higher than the figures usually cited in literature. This is partly due to the difficulty the analysts have in establishing full costs on a general basis. The local community as "sweat equity" is mostly providing labour without being paid for it. Their motivation is to get electricity in their houses. In addition it is not clear how much other type of costs are included in the calculations of the systems compared, for instance, how much of the distribution cost, or house wiring, how much of the cost of the civil works contribute to water management and irrigation, and so on. Following conclusion can be made:

Costs are highly site and country specific, are controllable with good management, proper sizing and suitable standards.

Table 49: Conclusion on Costs for Small Hydropower

To make the supplied energy useful, systems also require substantial investment in end-use technologies. Furthermore, MHP has a major advantage. It can be built locally at considerably less cost than it can be imported[204] from developed countries by developing local engineering capabilities and advisory services. An imported turbine (generating sets up to 100 kW) in Sri Lanka costs approximately Rs.50,000 to Rs.150,000 (US$700-2,000) per kW,

[202] Average cost in development countries according to ITDG.

[203] Source: *World Renewable Energy Congress VI*, Invited Paper.

[204] However, very inexpensive (but possibly unreliable) micro hydro equipment is sometimes available from China and other countries that are keen to obtain foreign exchange at almost any price.

while local manufacturers are now capable of delivering them at Rs.10,000 to Rs.15,000 (US$140-200) per kW, with marginally reduced turbine efficiencies.[205]

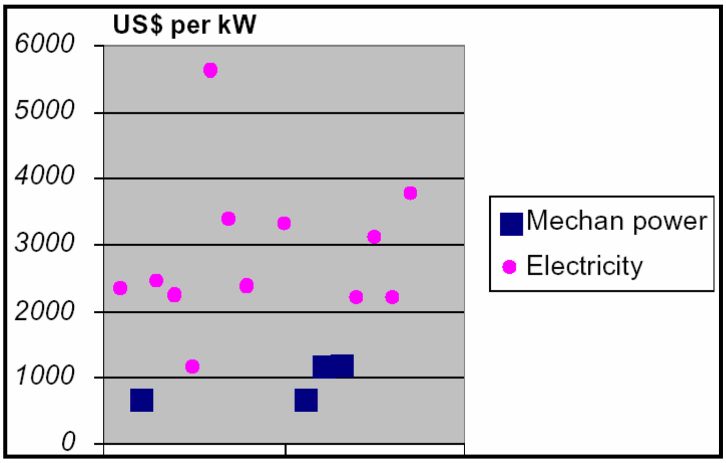

Figure 42: Cost per Installed kW (US$ 1998)[206]

6.9.2 Different Costs in High Head and Low Head Hydropower

As generally the economics primarily decides if the technology will be used or not there is a need to drive down the costs of SHP projects. Generally high head hydropower has least cost, since the higher the head, the less water is required for a given amount of energy and so the plant is smaller needing less costly equipment. For this reason can even quite small streams in mountainous regions, if used at high heads, yield significant power levels at attractively low costs. However, high head sites have the tendency to be in areas of low population density with low electricity demand. Additionally, long transmission distances to urban areas can nullify the low cost advantages of remote high head hydropower plants. Furthermore, high head sites are also relatively rare. Therefore, the greatest possibility for expanding the utilisation of SHP is with low head sites.[207]

There are many low head sites in Sri Lanka, like e.g. the estimated 30000 water storage reservoirs which have been built in the dry zone a long time ago. Nevertheless, most low head sites in Sri Lanka are economically unattractive compared with conventional fossil fuel electricity generation. Additionally, the low head turbine technology is still not manufactured locally in Sri Lanka making the economics even more unattractive. Therefore, many sites remain to be exploited best with turbines produced in Sri Lanka.

Another example is the UK which has some 20,000 disused water mill sites, all low head, which were once used but which have so far not been refurbished. There are many other countries in the world having a similar situation.[208]

[205] See *Best practices for sustainable development of micro hydro power in developing countries*, ITDG 2000.

[206] Source: *Best practices for sustainable development of micro hydro power in developing countries*, ITDG 2000.

[207] Compare s*mall hydro deserves to have its development accelerated in most parts of the world,* Peter Fraenkel, Renewable Energy World, March 1999.

[208] See ibid.

6.9.3 The Cost per Kilowatt Installed and Electricity Production Costs

The possessor of a good MHP will find that not only is the cost of a plant usually much less than thermal power plants and the transmission of the electricity. Furthermore, the cost of fuel is entirely done away with the cost of supervision, which is reduced to a minimum. If a MHP system is both well designed and constructed the wear and tear of a system is negligible as it is made for working always. Not to forget the hidden environmental costs resulting in greenhouse gas emissions and other environmental disadvantages arising through conventional power generation. Even when an engine is already at work, and there is only a small auxiliary water power available, it is both economical and wise to make use of it. Economical, as each kW taken from the load of the generator means a reduction of the electricity or petrol bill.

Generation source	Cost per installed kW (in US$)	Pricing per kWh (in US$)
Rehabilitation SHP	**750-1,500**	**0.05- 0.06**
New construction SHP	**1,200 – 3,000**	**0.05- 0.06**
New construction MHP	**~1,200**	**(3 – 6) Pricing monthly per 100 kW each household (in US$)**
Diesel	**1,000**	**0.03 – 0.15**

Table 50: Costs per kW & Tariffs for Different Generation Sources Fed to the Grid

The cost for a new installation of a small-scale hydro station is site-specific and varies from US$1200 -3000 per installed kW depending whether the turbine is manufactured locally or not.[209]

The cost for refitting old small hydro systems depends also from the location and varies from scheme to scheme. It is estimated that the cost of rehabilitating old hydro plants with turbines and generators manufactured locally, would range from US$750 to US$1,500 per installed kW. Accordingly, the cost of such power, based on a working life of 35 years, 10% interest on borrowed capital and with the usual provision for depreciation is between US$0.0468 and US$0.0175 per kilowatt hour (kWh) for average plant loads varying from 60 to 80%. The rehabilitation of the old small hydro installations could, therefore, be recovered within a few years.

6.9.4 Variable Power-Purchase Tariffs

Variable power-purchase tariffs can hinder market development. Grid-connected SHP projects are commercial initiatives carried out by private sector developers who sell the electricity generated to the Ceylon Electricity Board. CEB has agreed to set a standardised small power purchase agreement and tariff for grid-connected renewable energy power generation projects up to a capacity of 50 MW (earlier only 10 MW). In 1997 and 1998 tariffs were set at about US$5 cents/kWh and small hydro development flourished. However, because of the downturn in oil prices in 1998-99, prices were only of about US$3.5 cents/kWh in 1999. As a consequence, all development essentially stopped in 1999. These

[209] See *Best practices for sustainable development of micro hydro power in developing countries*, ITDG 2000.

rates were not increased in 2000 even though international oil prices doubled during 1999. And this fluctuation has seriously hurt the longer-term interest of private small hydro developers. The low tariffs and unresolved dispute on tariff calculation methods have caused a deep decline in small hydro development. The current tariff formula, based on the avoided cost principle is about US$6 cents/kWh (Rs.5.7 /kWh) in the dry season from February to April and about US$5 cents/kWh (Rs.4.95 /kWh) in the wet season). This *"tariff is based on a complicated formula, which involves the actual cost as well as projected costs, averaged over three years. Each year the rate fluctuates. So, if a low cost plant comes on board, like the Kukale Hydro power plant last year or combined cycles, the avoidance cost is bound to come down. This year, the tariff fell according to the formula."*[210]

6.9.5 Typical Case of a Sri Lankan MHP Project

Kithulritiela Village Micro-Hydro Project

The Kithulritiela village hydro project was implemented in the year 2001. *"With a capacity of 5.5kW provides electricity to 16 households and four small businesses, as well as to the temple in the village. The total cost of the hydro project was Rs.728,000 (about US$7,000).*

A loan of Rs.240,000 (US$2,400) repayable in five years has been obtained by the beneficiaries from the DFCC Bank under the World Bank Energy Service Delivery (ESD) project for the project construction work and its repayment is near completion. An Association of Electricity Consumers formed by the sixteen beneficiary households is responsible for the management, operation and maintenance of the hydro project. Each electricity-using household has to pay a monthly fee of Rs.150/- (US$1.50) for the electricity that they consume and another Rs.180/- (US$1.80) as their monthly loan instalment. The villagers use the electricity for lighting, television, radio and domestic appliances. In addition two local businesses use the power for battery charging, which provides battery power to households who do not yet have electricity connection. The power has improved two other enterprises in the village, one repairing radios and a tailoring business."[211]

6.9.6 How Do the Costs of Hydropower Compare with Other Options?

MHP is quite cost-effective. The type of energy services required must be considered. If minimum lighting is the only energy end-use required in remote locations and no falling water is available, photovoltaic may be the main alternative. It produces better light than kerosene, and is cheaper than dry cell batteries. But where falling water is available, MHP competes well with photovoltaic.

Fossil Fuels

Fossil fuels (particularly kerosene) are the main alternative to biomass fuel for poor people. It can be purchased in the tiny quantities and for the small sums of money, what make them affordable for poor people. It is to mention, that using kerosene has favourable environmental consequences. Professor Kirk Smith and others have shown that a switch from biomass to kerosene and LPG as a cooking fuel would result in a considerable reduction in

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[210] Quotation from *Power Politics*, online under: http://www.lankabusinessonline.com [2005.02.14].

[211] Quotation from *GATS and the threat to community electricity in Sri Lanka*, ITDG, 2004.

green house gases (GHG) per person meal. This is due to the considerably greater efficiency with which liquid and gas fuels can be converted into heat for cooking. Burning fuel in normal cooking fire or traditional stove is not "green house gas neutral" because of the products of incomplete combustion.[212] On the other hand kerosene (like e.g. used in kerosene lamps) has high risks to human health.

Micro hydro, like many other renewable energy options, are characterised by high initial capital costs, certainly higher than diesel systems. To some extent these costs are offset by relative low recurrent costs, resulting that poor people cannot afford this technology, even if the lifetime costs of these options is lowest.[213]

Diesel is the real bench-mark for MHP. Micro hydro can provide under right conditions the power, both electric and shaft power, to secure livelihoods through the utilisation of electric motors and other equipment for production. The cost for transporting the fuel has an additional contribute to the efficiency of diesel power plants. The cost of diesel generation in Sri Lanka is estimated to be about US$1,000 per kW installed. But the lack of trained technicians to provide regular maintenance is currently a hindrance to their further penetration into remote areas. Even so, some several thousands electric generators of less than 75 kVA were imported into Sri Lanka in 1996 at a cost of over US$ 10 million.[214]

In practice the critical factor is likely to be the availability and cost of transporting the fuel, and the extent to which the price of diesel and the system on which it is transported is subsidised.

It is also worth to know that the average consumption of most diesel generators is 0.35 l fuel / kWh. Approximately 1 kg CO_2 is released per each kWh produced.[215]

Grid Extension v. Decentralised Micro Hydro Electrification for Isolated Communities

Whilst supplying improved energy services to people for the first time is difficult, supplying such services to very poor people who live far away from roads where electricity grid poses a particularly difficult challenge. This section shows that SHP, especially MHP competes well with other energy supply technologies in these difficult markets. Despite this MHP appears to have been relatively neglected by donors, the private sector and governments in this allocation of funds and attention. In the past the option favoured by donors for rural electrification was through difficult grid extension. More recently the fashion has switched towards photovoltaic (PV), probably because of its higher foreign content, and the higher added value returned to the metropolitan countries. The relative neglect of MHP has also been part due to the fact that the circumstances under which it is financially profitable have not been systematically established, at least not in ways that investors find credible.[216]

According to an investigation conducted by the Energy Conservation Fund on the rural energy demand and supply in the North Western province, 24% of rural households use automobile batteries for lighting or to operate minor electrical appliances like television and

[212] Compare *Report for the US EPA Green House Gases from Small Scale combustion Devices in Developing Countries Phase IIA Household stoves in India*, Kirk Smith, et al, 1998.

[213] See Fig 3.1 and Table 4.1, *World Bank, Rural Energy and Development*, 1996.

[214] See *Feasibility of Dendro Power based Electricity Generation in Sri Lanka*, Energy Forum, Sri Lanka, 1998.

[215] Compare *Enhancing local content in the Mini Hydro Sector*, GTZ, Seoul, Korea, 2004.

[216] Compare *Best practices for sustainable development of micro hydro power in developing countries*, ITDG, 2000, p. 1.

radio. Most of the battery users have to travel over 2 km to reach a battery charging centre whilst 40% of them spend over Rs.40 (US$0.6) per month to recharge them.

According the ESD project, grid extension costs Rs.65,000 (US$650) per house, plus an additional Rs.15,000 (US$150) for connection fees. A PV system, on the other hand, costs only Rs.45,000 (US$450) per house. Surely grid extension makes more economic sense since it has fewer limitations, and has additional benefits like e.g. utilisation for income generation purposes. This figure would increase many times over, since entire areas would be connected at one time. This would be a very large financial commitment. Grid extension is also a political issue. The Council identified villages that would not be electrified in the next five years. According to the CEB, anything over Rs.50,000 (US$500) per household would not be included in the next round of electrification. Even with grid extension, there are still 4 million people in Sri Lanka that would not be able to access the grid.[217]

When the grid extends to areas that are electrified through MHP, power plant and distribution systems need to be developed being compatible with the grid – in compliance with industry standards. Under the World Bank ESD project, MHP schemes must comply with World Bank standards. Higher priority will be given to non-electrified areas. In some places, grid and micro hydro electricity are used in conjunction with each other.[218]

6.9.7 Micro Hydro can be Financially Profitable

The profitability can be measured using an internal rate of return (IRR) and a return on capital invested. According to ITDG experience shows a wide range of financial profitability and some interesting common features. There are plants that can be run without subsidy. These projects have a constant price rate of return of more than 8%, like for example the plant Seetha Eliya (12.4%), producing mechanical power for a profitable end-use such milling.

If plants are used exclusively for electric lighting, operating costs can usually be covered by electricity sales. However, the capital costs will have to be subsidised by grants.

"The analyses in current prices inevitably have higher IRR than those in constant prices. This is because tariff setting is often very poor and therefore the price of electricity is not being adjusted to keep pace with the rate of inflation. An important conclusion of the review is, therefore, that the financial return of many of the projects could have been improved considerably if the tariffs had been adjusted merely to keep level with inflation.

At more fundamental level, variation in financial performance of projects reviewed was due to variation in load factor. High load factors were achieved in schemes supplying mechanical power or electricity to motors rather than those installed primarily for lighting. Lighting for 4-5 hours a day can theoretically give maximum plant factors in the order of 0.15 to 0.20. This is indeed the typical plant factor for many micro hydro plants examined. In Nepal 90% of the schemes are supplying mechanical power. These schemes have a better profitability and can be financially sustainable in remote locations."[219]

The MHP industry is facing therefore a particularly difficult paradox. The main demand from consumers in Sri Lanka is for electric lighting, but most of the financially viable installations provide mechanical power to productive enterprises.

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[217] See *World Bank Support for Sustainable Energy in Sri Lanka*, online under: http://www.energyservices.lk [2005.11.17]

[218] Compare *ibid.*

[219] Quotation from *Best practices for sustainable development of micro hydro power in developing countries*, ITDG 2000, p. 14.

6.9.8 Cost Reduction Measures

Normally, MHP in rural areas of Sri Lanka can offer considerable financial benefits to the communities served, especially where careful planning identifies income-generating uses for the power.

"The major cost of a scheme is for site preparation and the capital cost of equipment. In general, unit cost decreases with a larger plant and with high heads of water. It could be argued that small-scale hydro technology does not bring with it the advantages of "economy of scale", but many costs normally associated with larger hydro schemes have been "designed out" or "planned out" of micro hydro systems to bring the unit cost in line with bigger schemes." [220] This includes the following innovations as:

- **using run-of-the-river schemes where possible - this does away with the cost of an expensive dam for water storage**
- **locally manufactured equipment where possible and appropriate**
- **use of HDPE (plastic) penstocks where appropriate**
- **electronic load controller - allows the power plant to be left unattended, thereby reducing labour costs, and introduce useful by-products such as battery charging or water heating as dump loads for surplus power; also does away with bulky and expensive mechanical control gear**
- **using existing infrastructure, for example, a canal which serves an irrigation scheme**
- **siting of power close to village to avoid expensive high voltage distribution equipment such as transformers**
- **using pumps as turbines (PAT) - in some circumstances standard pumps can be used "in reverse" as turbines; this reduces costs, delivery time, and makes for simple installation and maintenance**
- **using motors as generators - as with the PAT idea, motors can be run 'in reverse' and used as generators; pumps are usually purchased with a motor fitted and the whole unit can be used as a turbine/generator set**
- **use of local materials for the civil works**
- **use of community labour**
- **good planning for a high plant factor and well balanced load pattern (energy demand fluctuation throughout the day)**
- **low-cost connections for domestic users**
- **self-cleaning intake screens - this is a recent innovation which is fitted to the intake weir and prevents stones and silt from entering the headrace canal; this does away with the need for overspill and de-silting structures along the headrace canal and also means that, in many cases, the canal can be replaced by a low-pressure conduit buried beneath the ground - this technology is, at present, still in its early stages of dissemination**

Table 51: Innovations in Cost Reduction in MHP Development[221]

[220] Quotation from: Micro Hydro Power, ITDG Technical Brief, 2000.

[221] Adapted from: ibid.

7 Conclusion

It has been estimated that there are 200 MW of small water power sites up to a capacity of 5 MW and a further 250-300 MW sites between 5 MW and 25 MW. This total potential of around 500 MW is over 25% of the island's installed grid capacity as at 2003. And there are even more resources which are not recorded up to date, as the most actual literature for small hydropower found is from the year 2000. Sri Lanka's tremendous irrigation system, located mainly on the islands dry zone, offers surely more small hydropower low head sites as it was surveyed so far (8 MW).

Besides reactivating the numerous existing retired small hydro stations in the plantation area, it would be advantageous to construct many new small or micro hydropower plants.

The expansion of small-scale hydropower in Sri Lanka for the coming 10 years is expected to be between 200 MW and 300 MW.

If Sri Lanka's electricity demand continues with the prevailing expansion factor of 7% annually and Sri Lanka has still no solution for the energy question the energy crisis will not be solved.

In future, the use of hydropower, especially for electrifying remote communities must remain the main support for the country's electricity supply. It has so many advantages such as cost-effectively, sustainability, reliability, environmental compatibility, independency from overseas and much more. Therefore, Sri Lanka should ensure hydropower, one of her most reliable natural resources play an increased important role in the nation's future electrification plans, especially in rural communities. Small-scale hydropower has a future, not only in Sri Lanka.

7.1.1 Proposals by Author

- The long term goal is the systematic development of small-scale hydro as a supplementary source of energy to meet partly Sri Lanka's national electricity demand, especially in remote communities and additionally
- To ensure the maximum amount of renewable energy availability needed for economic activities.
- The immediate objective is to provide private power developers with ready access to the basic information on small hydro sites on the island, best also in the internet.
- Old estate micro and small hydropower installation which fell into disuse should be reactivated as soon as possible and new ones should be developed. The existing new estate sites in the range of off-grid rural areas should be new built without overloading the existing manufacturing capacities.
- Technology transfer (low head turbines up to 30 m) efforts between Sri Lanka and European enterprises should be made if possible. But in India, Nepal and China the situation has both similar circumstances to Sri Lanka and the needed technology.
- If micro hydropower is not feasible in an area, solar energy, wind energy or other forms like biomass should be considered.
- Private-Public Partnerships are essential to further develop the area so they become independent of donor aid programmes. The Uva province solar PV project is a good example of private-public partnerships.

Table 52: Proposals by Author for Future Action

7.1.2 The Lessons Learned in 14 Years of Practice

- The MHP industry is facing a particularly difficult paradox. The main demand from consumers in Sri Lanka is for electric lighting, but most of the financially viable installations provide mechanical power to productive enterprises.
- It may well be that micro hydro should be promoted for its role in securing livelihoods, or developing small enterprises, rather than as an "energy programme".
- Regulations should be set so that: independent power producers can supply power to the grid at 'realistic' prices; and connection standards are appropriate for the power to be sold. Rules should be transparent and stable.
- Costs are highly site and country specific, are controllable with good management, proper sizing and suitable standards.
- Quality and safety standards should be enforced to prevent the users being exploited by shoddy equipment and installations.
- While government finance tends to favour large scale energy investments (in say large hydropower or fossil fuels), micro hydro has the opportunity of utilising local capital (even the creation of capital through direct labour to build civil works) and it is part of the new trend towards "distributed" power with much reduced costs of transmission.
- Financially self-sustaining projects have cash generating (usually day time) end-uses to produce cash flow and increase the use of the plant (load factor). Lighting-only systems will have the greatest difficulty in achieving financial sustainability.
- Subsidies are likely to be necessary if micro hydro schemes are to substantially improve the access of poor people to electricity.
- Selecting and acquiring micro hydro technology that is appropriate to the location and task remains a necessary condition for success (wrongly sized plant and inappropriate standards remain a constant threat).
- It is easier to make a profitable micro hydro plant socially beneficial than to make a socially beneficial plant profitable
- Regulations should be set so that: independent power producers can supply power to the grid at 'realistic' prices; and connection standards are appropriate for the power to be sold. Rules should be transparent and stable.
- Best practice suggests that the expansion of micro hydro will continue to need both "soft funds" and funds at commercial rates, particularly if micro hydro is to meet the needs of people with low money incomes.
- Funding will be needed to cover capital costs, technical assistance and social/organisational "intermediation".

Table 53: Lessons Learned in 14 Years of SHP Practice, source: Mainly ITDG[222]

[222] Adapted from *Best practices for sustainable development of micro hydro power in developing countries*, ITDG 2000.

Although small-scale hydro power has been promoted by various policy initiatives in the past decades the use and development of this renewable energy source was not widely spread. The interventions and other supporting activities initiated mainly by the ITDG in the last two decades are explained below:

- Provision of technical assistance in the early phase of rehabilitating abandoned micro hydro plants in the Plantation Sector
- Developing the local engineering capabilities in design, operation and maintenance of small hydro plants
- Provision of O & M training for operators and mechanics engaged in small hydro plants
- Technical assistance towards manufacture of Pelton turbines
- Technical assistance towards the manufacture of Electronic Load Controllers (ELC) and Induction Generator Controllers (IGC)
- Demonstration and promotion of decentralised, community managed, micro hydro schemes to provide basic electricity needs of people in remote villages lacking access to the national grid.
- Inclusion of village hydro in the National Energy Policy.

The Government has so far undertaken two projects with the assistance of the World Bank. One is titled The Energy Services Delivery Project (1997-2002) and the other Renewable Energy for Rural Economic Development (RERED). The ESD Project was instrumental in the installation of 18,600 solar home systems (totally 875 kW), 56 off-grid Village hydro projects (aggregate capacity of 574 kW) benefiting 2,900 homes and 15 grid-connected small hydro projects generating a total of 31 MW. The RERED Project actively supports Sri Lanka's vision of expanding rural electricity access to at least 75% by 2007. Up to date there are 21 grid-connected small hydro projects with an aggregate potential of 58 MW and 68 off-grid village hydro projects (748 KW) approved and in development.

Nowadays, especially because of the ESD and RERED project, micro hydropower for off-grid electrification is getting more and more attractive. In November 2003 for instance, there were 161 off-grid micro hydro power (MHP) stations with a total capacity of 1622 kW in operation providing basic electricity needs of 3,687 households. Even if the power outcome is relatively low this is seen very successful due to remarkable achievements in terms of the number of units and households electrified. It is estimated that there are still about 1.023 micro hydro power off-grid locations having an aggregate capacity of about 41,5 MW. This could serve at least 50.000-200.000 households in remote areas to decrease the total number of about 2 million un-electrified households nationwide.

More than ten years of off-grid energy market development has created much awareness of the role of technologies such as Solar PV and MHP. However, there are yet some general barriers at the government level.

- Off-grid energy is not incorporated into mainstream energy policy, which only focuses on large scale generation and grid extension. Politicians yet offer grid extension for votes.
- The Electricity Act allows only the CEB to generate and sell electricity to consumers. As such, the micro hydro projects are not legal. They operate as independent cooperatives and charge a membership fee from consumers (ECS).
- Funding will be a problem once the World Bank project RERED ends.

Attention must be paid to proper structure of power-purchase tariffs so that renewable energy receives credit for the value it creates, in terms of both energy and capacity. So far, there are no cases, in Sri Lanka, where power production is linked with providing rewards to service providers. However, the existing energy conservation fund could act as an intermediary facilitating some sort of transfer between environmental service providers and beneficiaries.

There is a lack to be filled as the political goal is to reach 100% electrification rate but the grid based rural electrification or diesel generators in remote areas is very costly. Off-grid electrification technologies such as micro hydro, solar and wind (when available) could fill this gap wherever they emerge as cost-effective options. Especially, it is necessary to investigate the viability of these technologies in situations where the load is prevailingly domestic lightning and also when the consumption per household is relatively low.

Despite all this, it is still the kerosene lamps that provide light for over a half of the 3 million students in Sri Lanka; it is still the imported mineral oil that provides fuel for over a half of Sri Lanka's population. The time has now come to put a stop to that dependency through use of locally available and renewable energy sources. A new era of empowerment has begun, which will be fully realized only when this "powerless" 35% of the nation has gained access to an environmentally friendly and efficient power source, maybe through the installation of many more village hydro schemes.[223]

[223] See *Micro Hydro in Sri Lanka*, Lahiru Perera, Tilak Karunaratne, TCDC Training Workshop on SHP, 2002

7.2 Recommendations

7.2.1 Actions and Strategies proposed by ITDG

ITDG Sri Lanka drew up a plan to tackle the prevailing issues in order to guarantee that micro hydro power is ready to take up the challenge of electrifying the remote segments having no or little hope of grid electricity. The actions and strategies proposed by ITDG Sri Lanka are as follows: [224]

1. Setting up standards and regulatory mechanisms to maintain quality and standards of equipment and services.
2. Building capacities at supplier/manufacturer level through training and formation of an association among suppliers.
3. Facilitation of technology development and transfer.
4. Networking between key partners.
5. Legal status of off-grid community based micro hydro systems.

Table 54: Actions and Strategies Proposed for the MHP Sector by ITDG

Detailed information about these recommendations is given below.

Setting up Standards and Regulatory Mechanisms to Maintain Quality and Standards of Equipment and Services

It is essential to improve the quality of the equipment and services. Therefore proper standards should be developed and enacted. Through a certifying mechanism the equipment quality could be monitored. Institutions such as National Engineering Research and Development (NERD) centre could be commissioned to perform testing and develop the necessary infrastructure to carry out these tests.

Experience shows that the community gets his know-how mainly by the equipment supplier. As one of the draw backs in the recent failures of the system is due to lack of technical knowledge among the communities on operation, maintenance and trouble shooting measures it is necessary to set up guide lines for the suppliers to follow necessary steps to secure proper know-how transfer to communities.

Building Capacities at Supplier/Manufacturer Level through Training and Formation of an Association among Suppliers

Training

According to manufacturers it is a priority to carry out training programmes on the areas needing further knowledge and expertise. Two critical areas are identified by the suppliers:

- **Low head hydro designing (on workshop level) and manufacturing**
- **and designing of Induction Generator Controller for more than 25 kW generators**

[224] The contents of this 7.1 are mainly taken from *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* ITDG-South Asia, Nov. 2003 as long as no other source is given.

Table 55: Critical Areas Needing Training for Manufacturers

Furthermore, there is a vacuum created by the high demand and low supply due to the number of manufacturers. Therefore, their number should be increased by theoretical and practical training of the prospective technicians.

Formation of an Association among Suppliers

The benefits of such an association are expected to be

- **creation of a conducive business atmosphere,**
- **maintain and improve the quality and standards of the equipment and services provided,**
- **accessing support from government,**
- **bi lateral and multilateral donor and private agencies for equipment development and manufacture,**
- **raise the profile of equipment suppliers and manufacturers as important professionals in the industry,**
- **strengthening linkages between members and other stakeholders in the micro hydro industry, and**
- **putting in a team effort to resolve problems encountered by the suppliers.**

Table 56: Benefits of a Formation of an Association among Suppliers[225]

Facilitation of Technology Development and Transfer

The technology which was introduced in the early nineties in Sri Lanka remains still the same without any further developments. On the one hand there are no further technology developments in then country and on the other hand new developments in other countries such as Nepal, India and China are not transferred to Sri Lanka. Therefore, it is urgently needed to facilitate R&D through universities and other institutions and link up with other countries such as Nepal, India and China.

According to Dr. Nishantha there is lack in new developments in the turbine manufacturing technology in order to use new type of turbines. Remaining components of a hydropower scheme like turbine housings, generators, controls or switchgear are already manufactured successfully in Sri Lanka or imported from India, Nepal or China.[226]

Technology transfer is especially in the low head hydropower sector required in order to harness numerous low head sites of the islands tremendous irrigation system.[227] Mr Harsha from the Energy Conservation Fund emphasized the need low head turbines like e.g. Cross Flow turbines below 30 m in order to feed the national electricity grid. Designs between 30 m and 100 m are already manufactured locally [228]

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[225] Adapted from *Secrets of its success; Micro hydro taking the challenge of electrifying rural Sri Lanka,* J. Gunasekera, Technology Programme Leader ITDG-South Asia, Nov. 2003.

[226] Interview with Dr. Nishantha Nanayakkara, Head of the Small Power Developers Association in Sri Lanka, 11.2004.

[227] According to Mendis it is estimated that about 30000 water storage reservoirs have been built in the dry zone, in an area of about 15000 square miles.

[228] Mr Harsha, Energy Conservation Fund, Sri Lanka, 25.11.2004.

Networking between Key Partners

Presently, linkages between the manufacturers, importers of electro-mechanical components, researchers and design engineers seem to be very weak.

It is recommended to facilitate networking and communication within the manufacturers, technicians, researchers and importers in order to share the special expertise each individual has. It is also important to maintain good and uniform quality standards and prices among them.

Legal Status of Off Grid Community Based Micro Hydro Systems

As the implications of the Power Sector Reforms and privatisation of public utilities in Sri Lanka are not favourable for rural electrification and off grid systems it is very important to create awareness among the policy makers in order to adverse the effects. So far, ITDG and other organisations have organised awareness creation workshops, sent letters to relevant policy makers and written news paper articles on the concerns that need urgent attention.

Furthermore, the willingness of the CEB to purchase power and stability of the purchase tariffs should be guaranteed. CEB should not place bureaucratic obstacles in the path of SHP developers. These cause only developers leaving their development plans in frustration.

7.3 The next important steps for the Electricity Consumers' Society's (ECS):

- reviewing its efforts to produce and share energy, and get the same replicated
- developing grid-connected village hydro schemes, managed and maintained by the ECS as an income-generating project for other village development work
- continuously monitoring of the project. Essentially, this is an effort to share its capabilities with others, while consolidating the current achievements.

Table 57: Next Steps for the Electricity Consumer Society's (ECS) [229]

In Conclusion

Despite all this, it is still the kerosene lamps that provide light for over a half of the 3 million students in Sri Lanka; it is still the imported mineral oil that provides fuel for over a half of Sri Lanka's population. The time has now come to put a stop to that dependency through use of locally available and renewable energy sources. A new era of empowerment has begun, which will be fully realized only when this "powerless" 35% of the nation has gained access to an environmentally friendly and efficient power source, maybe through the installation of many more village hydro schemes.[230]

[229] Adapted from *Micro Hydro in Sri Lanka*, Lahiru Perera, Tilak Karunaratne, TCDC Training Workshop on SHP, 2002

[230] compare ibid.

Solemn Affirmation

I hereby solemnly explain that I prepared the following work independently. Thoughts which are taken directly or indirectly from foreign sources are as such identified.

The report has previously been presented to another examination authority, the University of Moratuwa in Sri Lanka.

Munich, the 27.02.2005

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Abbreviations and Acronyms

ADB	Asian Development Bank
ADF	Average Daily Flow
AU	Administrative Unit
BOO	Build Own and Operate
BOOT	Build Own Operate Transfer
BOT	Build Own and Transfer
CEB	Ceylon Electricity Board
DSM	Demand Side Management
ECF	Energy Conservation Fund
ECS	Electricity Consumer Societies
ELC	Electronic Load Controller
ESD	Energy Service Delivery
FDC	Flow Duration Curve
GEF	Global Environment Facility
GOSL	Government of Sri Lanka
GTZ	German Technical Cooperation Agency
GWh	Giga Watt Hour
IPP	Independent Power Producer
IRDP	Integrated Rural Development Project
IRN	International Rivers Network
ITDG	Intermediate Technology Development Group
Ktoe	Kilotons of oil equivalent
kW	Kilowatt
LECO	Lanka Electricity Company
MHP	Micro Hydropower
MW	Megawatt
NERDC	National Engineering Research and Development Centre
NGO	Non Governmental Organisation
PCI	Participating Credit Institutions
PPA	Individual Power Purchase Agreement
RE	Rural Electrification
RERED	Renewable Energies for Rural Economic Development
Rs.	Sri Lankan Rupees, 100 Rs ~1 US$ (2004)
SAARC	South Asian Association for Regional Cooperation
SARI	South Asia Regional Initiative
SHP	Small Hydropower
SHS	Solar Home Systems
SPPA	Standard Power Purchase Agreement
TUM	Technical University of Munich
TWh	Terra Watt hour
UoM	University of Moratuwa
US$	United States Dollar
USAID	United States Agency for International Development
kVA	Kilo Volt Ampere

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This study is predominantly based on secondary data available from various sources relevant to the power sector and small-scale hydropower development in Sri Lanka and information collected from different government official of the agencies and from personal knowledge acquired during the stay in Sri Lanka. The table below presents the details of the references and resource database reviewed and used in the present study.

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Appendix

A.1 Tips and Tricks to Save Energy in General.[231]

- Electric lighting adds heat to a space that must be removed in the summer by air conditioning. Turn lights off when not in use.
- Close the fireplace damper tight when the heating season is over.
- A 40 watt incandescent lamp and a 40 fluorescent bulb use the same amount of electricity, but the fluorescent lamp creates five times as much light.
- Don't block the supply air or return air ducts to the air conditioning system with furniture or drapes.
- Keep doors open in all rooms cooled by a central air conditioning system so that supply air can return easily to the unit.
- Be sure the air conditioning system is fully charged with freon so it will operate most efficiently when you need it.
- Check your auto and home air conditioning systems for freon leaks and repair them properly. Freon damages the ozone layer.
- When the weather is nice outside leave the AC off and open the windows.
- Duct air to ice machine condenser instead of using conditioned air that is exhausted to the outside. That way the heat generated by the condenser never enters the air conditioned space.
- Shop around for energy efficient computers, monitors and accessories.
- Use the kitchen exhaust fan when cooking to vent humid and odorous air.
- Be sure to open the windows now and again to air out the house or business. Fresh air is vital to human activity.
- Collect rain water in a cistern for watering plants, garden and landscaping.
- Plants help to purify air in the home. They extract carbon dioxide and create oxygen.
- Inadequate ventilation in an office or home can result in the "sick building" syndrome and possible illness to people within. Problems can range from dizziness or headaches to allergies or worse.
- Turn all the lights and equipment off in the office when you go home for the night.
- Use electric instead of gas powered lawn and garden equipment, as they create less pollution and are usually more efficient.
- Solar screens on south and west facing windows will reduce the cooling load of a building in the heat of the summer.
- Plant shrubs and trees around the air conditioning condenser to improve its operating efficiency. The shade makes it work less to cool the refrigerant circulating from the inside air handler.
- Clean out bird nests and debris from attic louvers so that air can flow freely through the attic space. Your home will be cooler.
- Teach your employees the intrinsic value of energy and the importance of conserving non-renewable resources such as coal or oil.
- Plant grass or ground cover on exposed land to prevent loss of topsoil from erosion. Landscaping also reduces the amount of reflected heat reaching the building shell.
- Organize a recycling program at your office or school and show everyone the savings possible.
- Teach your employees respect for nature, it will be a lifelong joy and benefit to them.
- Ride a bicycle or walk to work when the weather is temperate.
- Turn the water heater setting down a few degrees and reduce the amount of electricity you use. A typical home uses 30% or more of the electric bill on hot water.

[231] According to *General Tips & Tricks*, online under: http://energy.saving.nu/tips/general.shtml [2004.10.10].

- Using less hot water around the house saves energy too. Launder clothes in cold or warm water, take a shower instead of a bath or install a flow restrictor on the kitchen or utility room sink.
- Install a timer on the hot water heater and turn it on only for a couple of hours each day when all the domestic chores are done.
- Drying clothes on a line instead of in a dryer uses less energy and is easier on the fabric too.
- The coils at the back of the refrigerator are heat exchange surfaces. Keep them clean and the unit will operate at peak efficiency.
- Standing with the refrigerator door open lets humid air in. This makes it harder to cool and it will condense in the freezer into ice.
- Manual defrost refrigerators use less energy than automatic defrost models.
- Clean air conditioning ducts in older homes and businesses to increase the efficiency of the air conditioning system and save on the bills.
- Exhaust all the hot humid air from the restroom after bathing, as the humid air puts a heavy burden on the air conditioning system.
- Put a brick or bottle full of water in the commode reservoir to reduce water use.
- Plant natural grasses and shrubs that are native to your area and that do not require a lot of extra water in the summer.
- Defrost the freezer regularly to keep ice from building up on the coils and making the unit operate less efficiently.
- Wear lighter clothing in warm weather and raise the AC thermostat.
- Modify the office dress code so people can dress more casually and be comfortable with the thermostat set a few degrees higher.
- Heat your pool the smart way - purchase a solar blanket and let the sun do it.
- Put lower wattage bulbs in fixtures that are used for area lighting or exterior lighting.
- Use an inexpensive photoelectric light for nighttime lighting in the yard or home so the lights burn only when it is dark outside.
- Motion sensors will turn on outside security lighting only when movement is detected within its range and keep from running the lights all the time.
- Solar film installed on the south and west windows will keep the house cooler in the summer.
- Replace inefficient incandescent outside flood lights with more efficient high pressure sodium or low pressure sodium lamps. The latter are better in areas with bug problems.
- Use ceiling fans in classrooms and offices to circulate the air in the summer and to move warm air down from the ceiling in the winter.
- Clean the lens of fluorescent fixtures periodically so the light transmittance losses are minimized.
- Purchase efficient replacement lamps when the present bulbs burn out.
- Remove concealment and bushes that are so near AC condensing units that they restrict the flow of air.
- Repair holes and broken seams in ductwork to be sure all the conditioned air arrives at the occupied spaces and is not lost in the attic or ceiling space.
- Install extra insulation in the attic to reduce your bills year round.
- Replace incandescent lamps with compact fluorescent lamps for up to 80% reduction in electricity use.
- Repair caulking and weather-stripping around doors and windows to weatherize your home to be easier to heat and cool.
- Open blinds and curtains in the winter to let the sun heat up a space in the winter, then close them at night or when it is cloudy outside.
- Changing air filters for the air conditioning monthly during times of high use will keep the equipment working at peak efficiency.
- Do not use the kitchen stove to heat rooms.
- Keep the lawn grass a little longer in real hot weather - it will use less water and be healthier.
- Turn the screen off on the computer terminal at work when you will not be using it for a while.

- Leave lawn clippings after mowing to fertilize the grass, or collect the clippings and use them for much.
- Save old binders and computer paper from the office for schools in the neighbourhood.
- Remove old items from the refrigerator regularly so you don't waste electricity keeping them cold all the time.
- Re-use waste basket liners around the office.
- Bring old documents and papers to a printer and recycle them into scratch pads for use around the office.
- Use the water from cooking vegetables to make soup.
- Discover the extent of the watershed supplying the aquifer or water table in your area and practice clean water use within its bounds.
- Walk the golf course instead of driving a golf cart.
- Sweep and rake by hand instead of using a power blower.
- Buy certified organic produce and frequent farmer's markets.
- Double pane the windows or purchase storm windows.
- Purchase home and automobile air conditioning equipment that uses freon with a low ozone depletion potential.
- Install a motion sensor to turn off lights in offices and spaces with erratic occupancies such as restrooms and mechanical rooms.
- Use a combination photocell-switch to turn off lighting in offices or rooms with day lighting available much of the day.
- Drive the speed limit and save diesel or gasoline.
- When purchasing replacement appliances buy the energy efficient types.
- Turn off lights, radios, televisions and other items when they are not being used.
- Plant evergreen trees to break the strong winter winds before they reach your home or office building.
- Install a replacement roof on your home that is light in color if the summers are extreme. Your air conditioning will work less to keep your home cool.
- Radiant barriers in the attic space prevent much thermal energy from entering the occupied space and burdening the air conditioning.
- Clean out the drain pan of the air conditioning unit regularly to prevent bacterial growth from spawning there, then entering the air.
- If air is moving well, such as from a ceiling fan, it can be a little warmer and still give the sensation of being comfortably cool.
- Many ceiling fans can be operated in reverse in the winter to push warm air down from the ceiling to the occupied spaces.
- Store cleaning materials in tightly closed containers so fumes cannot leak into the air.
- The presence of respirable particles can affect the health and productivity of building occupants.
- Too much light on the desk surface can be just as harmful to the eyes as too little. Most offices are overlit, especially if the overhead lighting is supplemented by day lighting from windows.
- A typical air conditioning system should supply 20% fresh air to all the conditioned zones.
- Clean the air conditioning return and supply diffuser grills regularly to save fan horsepower and keep the air stream cleaner.
- Air conditioning ductwork can be the source of microbial growth over time, especially in a damp environment. Metal ducts can be cleaned.
- Keep circulating air out of a building for a few hours once a week after hours to circulate all the carbon dioxide built up.
- Turn on the heat or air conditioning an hour or two before leaving and the office will continue to be comfortable until the close of business.
- Abundant shade, greenery and grass around a home keep the building cooler and easier to cool.

- Tune up the car engine regularly to maintain the gas mileage at its highest possible level.
- Tilt blinds slightly to keep direct sunlight from entering a room and heating it up unnecessarily in the summer.
- Clean the attic louvers of nests, debris or other items that can block the flow of air and cause the attic to heat up.
- Many heating and air conditioning ducts in the attic or ceiling space of older homes are not insulated. Proper insulation will save a lot of energy and cause the system to operate more efficiently.
- Homes and businesses can lower the temperature of domestic hot water in the summer months and still provide adequate comfort and service.
- A programmable thermostat at home can turn the central unit up a few degrees after you go to sleep in the summer and during the day, for 105. A gas powered furnace or hot water heater located in the home must have adequate ventilation so the equipment has enough combustion air to perform at peak efficiency.
- Insulating hot water lines in the slab or crawl space will save on the water heating bills. Heat tape will further increase savings.
- Fax machines use only a seventh to half the energy needed to send a document by overnight delivery services.
- Active noise cancellation technology can reduce the energy consumed by large diesel engines by reducing the energy wasted in the muffler.
- A good electric heat pump can beat the resources-to-be-delivered efficiency of a gas furnace.
- Water outdoor shrubs before a hard freeze to protect them.
- Take shorter showers to save water and install a flow restrictor on the shower head. Shower instead of taking a full bath.
- An efficient air conditioning system for dry climates is the substantial savings. An evaporative precooler is a good idea for existing units as well and will make the packaged system more efficient.
- When buying a refrigerator, choose an energy efficient model. Side by side models are less efficient that other units.
- Automatic defrost refrigerators use more energy than manual defrost models.
- Use the lowest octane gas your car can tolerate without knocking.
- Roof and trunk racks on cars or trucks upset the body's aerodynamics and reduce gas mileage.
- Clean out heavy items such as tools from the trunk of your car. They are extra weight the car must move and so they reduce gas mileage.
- Irrigating efficiently saves water and for large acreages it saves pump energy as well.
- Protection of wooden structures exposed to the elements will make them last longer and look more appealing.
- Quality filter elements can help minimize airborne particles in the home that cause allergies. Electrostatic filters are quite effective.
- Excessive moisture in the air is bad for buildings during the cooling season. The humid air places an extra heavy burden on the air conditioning apparatus and can cause moldy curtains, walls and other surfaces.
- Check car fan belts regularly and change them when they become cracked, worn or oil soaked.
- If the freezer is not full already fill plastic jugs with water and keep them in the freezer compartment.
- Turn the water heater off when you are gone for a long weekend or on vacation for several days.
- Install a water saving toilet when it is time to replace or remodel. Many cities offer rebates to encourage water conserving appliances.
- Replace fluorescent lamps with more efficient models when they burn out.
- Many utilities offer rebates for high efficiency lighting retrofits.
- Turn HVAC systems off at night so fresh air can infiltrate naturally.

- Use the extra heat left over after cooking in the oven to do other tasks such as rising bread or warming food.
- Homes with basements can save on their heating and cooling bills by providing extra insulation in the basement.
- Run the dishwasher in the evening and open the door overnight so the dishes can drip dry.
- Plant shade trees in the yard, by roadways and in vacant lots.
- Comb the fins on the air conditioning condenser outside when they are mashed or disfigured to improve the heat exchange rate of the unit.
- Use smaller appliances such as pressure cookers, woks or broiler ovens instead of the full oven when cooking small portions.
- If you leave a room for more than 15 minutes turn off the lights and other appliances such as radios or televisions being used.
- You can turn off the oven or stove a few minutes before an item is finished cooking and the residual heat will finish the job.
- Most electrical appliances, such as motors, lights and electronic components generate heat that puts an extra burden on air conditioning.
- Tenant sub-metering is an effective energy conservation measure for large building owners.
- Enroll your company in the EPA's Green Lights program and learn how you can save on your utility bill.
- Purchase an inexpensive light meter and tailor the lighting throughout the office or business to the minimum lighting requirements. Most places are overlit - especially rooms with daylighting - and can benefit from lower wattages lamps.
- Reduce the exterior nighttime lighting for your business to the minimum for safety and publicity.
- Have building cleaning and maintenance personnel work during the day rather than at night when the air conditioning and lights must be on specifically for their activities.
- Home photovoltaics are an option for remote houses or equipment sheds.
- Don't open the refrigerator or freezer until you are sure what you will be getting. Keep a list of contents posted on the door with an inventory of contents.
- Close off air vents and keep the doors closed to rooms that are seldom used to save on air conditioning and heating costs.
- Reduce the risk of ocular problems by designing offices and workstations to provide the optimum light at the work surface.
- Use drapes and awnings to reduce the heat transferred through windows by closing them when a space is not currently in use. Even partially closed vertical or horizontal blinds help.
- Multi level light bulbs are energy savers if they are used at the lowest wattage whenever possible.
- Recycle magazines, notepaper and computer printouts along with the newspaper. Or bring them by your health club or doctor's office.
- Turn upper floor office lighting and accent lighting at night to reduce light pollution.
- Gravel, rock and asphalt surfaces prevent rain from soaking through to the water table and aquifer. Plant grass or ground cover where possible to help preserve an ecological balance.
- Find out if your business is charged a peak demand charge by the electric utility company and investigate ways to reduce that expense.
- Building operators can save money by operating only one elevator on weekends and at night.
- Interlocking security lighting with a motion sensor instead of an on-off switch or even a photocell will reduce the cost of operating it and give notice of intruders.
- Dimmers can reduce the cost of lighting and cause a more healthy and effective lighting level, especially in spaces with several different functions.
- Multiple switching of fluorescent ceiling fixtures can save energy by turning on only as many lamps in each fixture as is necessary for adequate illumination.
- Reduce your use of electric appliances such as hole punchers, pencil sharpeners and copy machines.

- Turn the pilot flame of the furnace off at the end of the heating season so it does not burn all summer long unnecessarily.
- Plant wildflowers in vacant lots, roadsides and other public areas so that the grass will have to be mowed less frequently.
- Conserve paper around the office by making fewer copies and by using electronic storage and communication methods.
- Post general office notices on a bulletin board instead of circulating notices to each individual.
- Variable speed motors and controls on air handling units can save on cooling and heating costs.
- Replace fluorescent lamp ballasts with electronic ones and save.
- Buildings that have a hot water circulating system can save by turning the circulating pump and water heater off at night and on weekends.
- Donate old appliances, tools and electronics to charitable groups so they can repair them for the less fortunate.
- Recycle newspapers and save trees. They say that every Sunday edition of the New York Times uses a whole tree.
- Rehang misaligned windows and replace windows with broken or cracked panes.
- Reduce the quantities of air exhausted from kitchens, restrooms and laboratory vent hoods as much as practicable.
- For restrooms that exhaust constantly disables the air supply and let the space be conditioned by return air drawn in by the exhaust fan.
- Use a high efficiency filter for the air conditioning system to protect the fan, motor and air distribution system from build up of dust and dirt that reduce efficiency.
- Adjust exterior doors to minimize the crack all around so that air infiltration is minimized.
- Keep the refrigerator coils free of ice build up by defrosting at regular intervals.
- Water lawns early in the morning and long enough for a deep soak to encourage deep root growth.
- Fluorescent lighting is five times more efficient as incandescent.
- Spores and microbes can collect in carpet, furniture and drapes and impair the quality of the air indoors. Clean these items regularly.
- Businesses can save by turning the AC off at night or by setting it back a few degrees.
- Inadequate ventilation in an office or home can result in the "sick building" syndrome and possible illness to people within.
- Insulate the tubing from the air conditioning condenser outside to the fan and heat exchange coils inside.
- Thaw frozen foods in the refrigerator to take advantage of their low temperature.
- Preheat the oven for baked goods only and don't preheat sooner than is necessary.
- Recycle building materials such as bricks, masonry, timber, steel and ceramic tiles.
- The aluminium industry consumes 1.4% of the entire world's total energy. Recycle aluminium cans and other items.
- Recycle wood and wood products into chips for firing furnaces or for composite wood products.
- Landscape shading of walls and roof will conserve on summer utility bills.
- Purchase efficient heat pumps for your home or business.
- Solar hot water heaters are a renewable energy resource.
- Reduce lighting levels for non-critical tasks. Purchase an inexpensive light meter to check light levels against the standards.
- Concrete accounts for two thirds by weight of North America's demolition waste.
- Recycled steel comprises 66% of the new steel in the United States.
- Isolate storage rooms from occupied spaces and do not condition the air to them at all if possible.
- Turn off portable space heaters and fans when they are not needed and when the room is not occupied.

- Inspect all automatic doors for proper functioning. It is especially important that they close completely to minimize any air infiltration.
- Develop an after hours equipment check list by custodial and security personnel to ensure that all unnecessary equipment such as lights, typewriters and computers are not left on.
- Adjust the temperature control on the refrigerator and freezer to the warmest practical temperature.
- Locate the refrigerator away from the stove, a heating vent or where the sun will shine directly on it.
- Be sure there is enough clearance at the back of the refrigerator for air to circulate. The coils are heat exchange devices that transfer heat from the unit to the air by way of a circulating fluid inside.
- Store only foods that must be refrigerated in the icebox.
- Keep foods covered tightly to reduce moisture build-up in the icebox. It takes more energy to cool humid air than dry air.
- Wipe moisture from bottles and cartons before putting them in the refrigerator to be sure they do not add to the latent load.
- Establish rules and post them asking everyone to keep outside doors closed and to use them only as necessary.
- Cover the fresh air intake for through-the-wall air conditioning units when they are not used for a season to keep air from entering.
- Interlock restroom exhaust fans with the lights and control the lights with an occupancy sensor/switch combination so they operate only when the room is in use.
- Install a thermostat to control the attic fan so that it operates only when the temperature is ten or more degrees above ambient.
- Partially close attic vents and louvers in the winter so that warm air will remain in the ceiling space and not escape and are replaced with cold outside air. (allow for some ventilation)
- Purchase vents hoods that introduce a percentage of air as untreated outside air instead of exhausting 100% of conditioned air from the space. Existing vent hoods can sometimes be modified with this option for great savings.
- Gasket the bottom of all garage type doors if they enclose a conditioned space.
- Check the refrigerator door gasket and replace it if it is not sealing tight.
- Use heat tracing to keep hot water piping warm and adequately insulate the lines.
- Reuse old file folders, dividers and manila folders in the office by using new labels.
- Reduce the use of internal heat generating office equipment such as lights, computers and copying machines during the summer in exterior zones and all year long in interior zones.
- Turn all central HVAC equipment off by a fixed time clock schedule.
- Cooking with lids on pots and pans can reduce by half the heat required.
- Don't use hot water to rinse the kitchen dishes.
- Colored clothes do not have to be washed in warm or hot water. This wastes energy and causes the colors to fade.
- Clean the lint trap of the clothes dryer regularly to maximize the air flow within the machine.
- Consider replacing the pilot lights of gas burning furnaces and water heaters with electronic ignition devices.
- Natural light can be reflected deep into a room by reflective sills, blinds and other architectural features to supplement artificial lights.
- Keep auto mufflers and exhaust systems in good repair to reduce emissions and to keep the miles per gallon high.
- Operate kitchen exhaust hoods only when the cooking surfaces are actually in use.
- It is important to provide adequate ventilation when using kerosene space heaters or wood burning stoves. There must be sufficient oxygen available for complete combustion and the products of combustion must be vented from the occupied space.
- Use paints and toxic chemicals in a well ventilated space.

- Blue flames on a gas stove mean it is not adjusted right. The flames should be yellow.
- Ground source heat pumps are efficient and environmentally friendly.
- Electronic dimmers can cause harmonic distortion in a building's power distribution system. Avoid using them where equipment is sensitive to the quality of power.
- Calibrate thermostats so they maintain the right set point.
- Adjust the ceiling diffusers to spaces that are over or underheated. If the diffuser is not adjustable, replace it with one that is.
- Post signs near thermostats to remind people of the ideal setting.
- Consider automatic door closers on swinging exterior doors.
- Relocate thermostats if they are near outside walls, in seldom used areas, near heat sources or in a draft. The best position is near the return air grill on an inside wall.
- Thermally seal all unused windows.
- Add reflective or heat absorbing glazing to windows. They diminish the natural day lighting but can reduce the solar heat gain substantially.
- Reflective materials on the window side of draperies reflect solar heat when the curtains are closed.
- If roof insulation cannot be added, then put it at the top floor ceiling.
- Painting ceiling and walls with a lighter and more reflective paint, ceiling tiles or floor coverings will increase the light level in a room.
- Wash windows frequently to take best advantage of day lighting.
- Replace light fixture lenses that have become yellow or hazy with age with a clear acrylic lens that will permit the most light to pass.
- Water indoor plants more often in the winter because central heating dries the air out.
- Purchase an energy efficient home or upgrade your older home with the latest energy conserving materials and equipment.
- Keeps a kettle simmering on the oven to raise indoor humidity in the winter for increased comfort. You will also be able to turn the thermostat down a few degrees and still be comfortable.
- Move desks and work surfaces to take advantage of day lighting.
- Use room and area lighting only when it is needed.
- Arrange work surfaces so that sidewall day lighting crosses the task at a perpendicular angle to the line of vision.

A.2 Recommendations Reducing both Planned and Unplanned Interruptions in the Sri Lanka Power System.[232]

- Streamlining generating capacity additions, including using efficient procurement processes and encouraging private sector participation.
- Strengthening end-user participation in the electricity supply industry so that policymakers and planners consider their needs when taking initial decisions. This can be done by nominating representatives from institutes such as the Chamber of Commerce, Chamber of Industries and Federation of Chambers of Commerce and Industry to different committees dealing with power sector issues.
- Adoption of effective demand-side management strategies while encouraging consumers to use backup unit generation facilities to the maximum extent possible in the short-term, in order to help alleviate the current capacity shortage. This would require short-term incentives in the electricity tariff structure.

[232] According to *Economic Impact of Poor Power Quality on Industry*-Sri Lanka, 2003, p. 3, Prepared for: USAID-SARI/Energy Program, online under: www.sari-energy.org [2004.10.08].

- Operate the generation, transmission and distribution system in a more reliable manner through regular maintenance of facilities and with the use of proper operational management systems.
- Inclusion of power quality standards in the draft electricity act so that utilities are obliged to pursue cost-effective options to make sure that the quality of supply is maintained for the benefit of consumers.
- It is also recommended that studies to enhance the reliability of the Sri Lanka national power grid, including a study on system planning and operations be undertaken.

Table 58: Recommendations Reducing Planned and Unplanned Interruptions in Sri Lanka

Options to properly balance supply and demand with sufficient operating reserves to maintain network security include the following critical aspects.

On the generation side, more plants need to be built to meet the increased demand. To ensure that such generation is built several schemes may be considered. Private sector participation in electricity supply using build-own-operate-transfer (BOOT), build-own-operate, (BOO) and build-operate-transfer (BOT), for example, may be worthwhile options. From a procedural point of view, streamlining the process of capacity additions, particularly at the decision making level, is an essential step in getting projects online in a short period of time. In the long-term, it may be worthwhile to examine plans that reduce dependence on limited hydro resources and explore the use of other energy sources, such as LNG and wind.

On the demand side, reduction of effective demand on the system is a viable alternative. This could be achieved by promoting the use of more efficient end-use equipment and employing other cost-effective demand-side management techniques.

On the transmission side, infrastructure needs to be built and operated more efficiently. Use of Supervisory Control and Data Acquisition (SCADA) and advanced Energy Management Systems (EMS) could help the CEB to enhance system operations at all levels. Provision of wheeling arrangements, whereby excess generation at the customer level may be delivered to other power starved regions, may be an attractive short-term option that could be considered.

Unplanned outages, on the other hand, inevitably occur due to poor system reliability. Since, unplanned outages account for a significant portion of all outages, dealing with the problem of unplanned outages is critical. Most unplanned outages can be avoided by improving system reliability by considering the following aspects:

On the generation side, regular and periodic maintenance of generator equipment is necessary to ensure generator unit availability. Generation protection schemes should be overhauled to help ensure secure operation and improved unit availability.

On the transmission and distribution side, system reliability should be enhanced. This includes using meshed circuits as opposed to radial feeders, using underground cables in critical areas that are prone to weather-related problems, providing multiple feeds to critical customers, and enhancing protection schemes to detect and clear faults occurring on the system. In this context, more emphasis should be placed on the maintenance of distribution equipment as it has been shown statistically that outages usually are the result of problems in the distribution system, rather than in the generation sector.

A.3 Small Hydropower Projects Approved under the ESD Project

A.3.1 Grid Connected Small Hydro Projects Approved under ESD (as at 31 December 2001)

	Project Name	District	Province	Project/ Development/ Dealer	Installed Capacity KW
1	Bambara Balu Oya	Ratnapura	Sabaragamuwa	Vidulanka Limited	3,200
2	Erapura Ganga	Ratnapura	Sabaragamuwa	Ceylon MKN Eco Power Pvt Ltd	750
3	Carolina Estate	Nuwara-Eliya	Central	Mark Marine Services (Pvt) Ltd	2,500
4	Panakura Oya - Minuwanella	Kegalle	Sabaragamuwa	Sunro Company (Pvt) Ltd	320
5	Ellapita Ella-Maliboda Estate	Kegalle	Sabaragamuwa	Eco Power (Pvt) Ltd	550
6	Delgoda	Ratnapura	Sabaragamuwa	Zyrex Power Company Ltd	2,400
7	Glassaugh	Nuwara-Eliya	Central	Eco Power (Pvt) Ltd	2,526
8	Mandagal Oya-Maliboda Estate	Kegalle	Sabaragamuwa	Eco Power (Pvt) Ltd	1,271
9	Galaththa Oya-Pussellawa	Kandy	Central	Hydrodynamics (Pvt) Ltd	1,200
10	Medapiti Oya	Nuwara-Eliya	Central	Natural Power (Pvt) Ltd	1,500
11	Rat Ganga	Ratnapura	Sabaragamuwa	Eco Power (Pvt) Ltd	4,650
12	Nividu	Ratnapura	Sabaragamuwa	Nividu Lanka Ltd.	2,000
13	Naya Ganga Mini Hydro Power Project	Kegalle	Sabaragamuwa	IWS Power Grid Ltd.	1,000
14	Upper Watawala	Nuwara-Eliya	Central	Mark Hydro (Pvt) Ltd	1,300
15	Niriella	Ratnapura	Sabaragamuwa	Power Base Tech (Pvt) Ltd	3,000
16	Deiyanwala,Gantelgoda	Kegalle	Sabaragamuwa	Hydrojet	1,400
	Total				**29,567**

Table 59: Grid Connected Small Hydro Projects Approved by PCIs (as at 31 December 2001)[233]

[233]Source: Grid Connected Mini Hydro Projects Approved by PCIs, online under: http://www.lanka.net/esdp/whats_new.html# [2004.12.10].

A.3.2 Village Hydro Projects Implemented/Approved by PCIs (as at 31 December 2001)

	Project Name	District	Province	Number of Households		Installed Capacity in KW
				plan	Actual	
1	Madabaddara	Ratnapura	Sabaragamuwa	40	39	4.5
2	Pathavita	Matara	Southern	100	83	8.5
3	Kandaloya	Kegalle	Sabaragamuwa	80	80	10.0
4	Hettikanda-Marandola	Matara	Southern	21	21	7.0
5	Hardunella VH	Kegalle	Sabaraga muwa	50	50	13.0
6	Berannawa	Kegalle	Sabaragamuwa	59	59	6.0
7	Gedarawatta	Kegalle	Sabaragamuwa	40	40	12.0
8	Gollahinna/Kambili Oya	Kegalle	Sabaragamuwa	76	76	22.0
9	Kudaoya Electricity Project (Under Construction)	Kegalle	Sabaragamuwa	60	-	15.0
10	Kethigana Ela/Panwala (Under Construction)	Kegalle	Sabaragamuwa	25	-	7.5
11	Watagala (Under Construction)	Kegalle	Sabaragamuwa	60	-	10.0
12	Kawudubuluwa (Under Construction)	Kegalle	Sabaragamuwa	52	-	12.0
13	Panvila Arunalu (Under Construction)	Kegalle	Sabaragamuwa	50	-	12.0
14	Kitulritiella (Under Construction)	Kegalle	Sabaragamuwa	20	-	5.0
15	Veediyawatte	Kegalle	Sabaragamuwa	125	125	45.0
16	Samanala Kuda (Under Construction)	Kegalle	Sabaragamuwa	40	-	15.0
17	Ihala Gonna Kitulgala (Under Construction)	Kegalle	Sabaragamuwa	20	-	7.5
18	Gilme (Under Construction)	Kegalle	Sabaragamuwa	23	-	5.0
19	Ampana (Under Construction)	Kegalle	Sabaragamuwa	20	-	4.0
20	Dombepola (Under Construction)	Kegalle	Sabaragamuwa	36	-	10.0
21	Gowala (Under Construction)	Kegalle	Sabaragamuwa	37	-	4.5
22	Diyadoloella (Under Construction)	Kegalle	Sabaragamuwa	40	-	6.0

23	Welgala (Under Construction)	Kegalle	Sabaragamuwa	37	-	5.5
24	Egoda Amanawala (Under Construction)	Kegalle	Sabaragamuwa	44	-	4.5
25	Wathukarakanda (Under Construction)	Ratnapura	Sabaragamuwa	31	-	6
26	Sampath Ella (Under Construction)	Kegalle	Sabaragamuwa	52	-	10
27	Thanthirikanda (Under Construction)	Kegalle	Sabaragamuwa	50	-	7.5
28	Ihala Oluella (Under Construction)	Kegalle	Sabaragamuwa	60	-	12
	Total			**1348**	**573**	**287.0**
	Project Name	**District**	**Province**	**Number of Households**		**Installed Capacity in KW**
				plan	**Actual**	

Table 60: Village Hydro Projects Implemented/Approved by PCIs (as at 31 December 2001)[234]

[234] Source: *Village Hydro Projects Implemented/Approved by PCIs (as at 31 December 2001),* online under: http://www.lanka.net/esdp/villege_hydro.html [2004.12.10].

A.4 Status of Hydropower Projects Approved under RERED as at 30 September 2004

A.4.1 Status of Grid Connected Projects Approved under RERED as at 30 September 2004

Project Name and District	Location	PCI	Project Developer	Capacity kW	Status
Mini Hydro					
1. Sanquhar Estate	Udapalatha	HNB	Hydro Power Free Lanka (Pvt) Ltd	1,600	Commissioned 12 Dec 2003
2. Hulu Ganga	Panwila	HNB & CB	Eco Power (Pvt) Ltd	2,870	Commissioned 3 Jun 2003
3. Attabage	Udapalatha	HNB	Hydrodynamics(Pvt) Ltd.	2,000	wip1
Sub-total Kandy District				6,470	
1. Panakura Oya Minuwanella (expansion)	Deraniyagala	DFC C	Sunro Company (Pvt) Ltd	160	Commissioned 3 Jul 2002
2. Kandureliya	Deraniyagala	DFC C	Kandureliya Hydropower Ltd	750	Commissioned 26 Jan 2004
3. Wee Oya	Yatiyantota	DFC C,ND B	Powerbase Techonology (Pvt) Ltd	6,000	wip
4. Miyanawita	Deraniyagala	HNB	Midland Energy (Pvt) Ltd	600	wip
5. Nakkawita	Deraniyagala	HNB	Weswin Construction Nakkawita (Pvt) Ltd	1,200	Commissioned 17 Aug 2004
6. Assupiniella	Aranayaka	NDB	Nividhu Assupiniella	4,000	wip
7. Ritigaha Oya	Yatiyantota	NDB	Kalupahana Power Company (Pvt) Ltd	997	wip
8. Deiyanwala, Gantelgoda Ela	Aranayaka	Samp ath	Hydrojet	1,400	Commissioned Sep 2002
Sub-total Kegalle District				15,107	
1. Brunswick Estate	Maskeliya	DFC C & HNB	Maskeliya Plantations Ltd	600	Commissioned 18 Apr 2004
2. Kahawathura Oya	Ginigathhena	DFC C	Coolbawn Hydro (Pvt) Ltd.	1,200	wip
3. Radella	Nuwara Eliya	HNB	Thalawakelle Plantations Ltd	200	wip
4. Henfold Estate	Nuwara Eliya	NDB	Senok Mark Hydro (Pvt) Ltd	2,600	wip

5. Labuwewa Oya	Nuwara Eliya	NDB & Sampath	Acqua Power (Pvt) Ltd	2,000	wip
Sub-total Nuwara Eliya District				6,600	
1. Didul	Pelmadulla	DFCC	Didul (Pvt) Ltd	9,000	Commissioned 27 May 2004
2. Gampolawalakanda	Kalawana	DFCC	Pantak Power (Pvt) Ltd	3,800	wip2
3. Adawikanda and Pelendakanda	Kuruwita	DFCC, Sampath & CB	Zyrex Power Co Erathna Ltd	9,900	Commissioned 15 Jul 2004
4. Seethagala	Balangoda	HNB	Energy Reclamation (Pvt) Ltd	800	Commissioned 16 Apr 2004
5. Rathganga	Ratkurugala	HNB	Pan Asian Power (Pvt) Ltd.	2,000	Commissioned 5 Jul 2004
6. Belihul Oya	Imbulpe	HNB	Ceypower Cascades (Pvt) Ltd	2,400	wip
7. Alupola	Wewalwatte	NDB	Eco Power (Pvt) Ltd	2,449	Commissioned 16 Jun 2004
Sub-total Ratnapura District				30,349	
Total Hydro				58,526	
Wind				-	
Bio-Mass				-	
Walapane	Nuwara Eliya	NDB	Lanka Transformers Ltd	1,000	wip
Total Bio-Mass				1,000	
Total Grid Connected				59,526	
Project Name and District	**Location**	**PCI**	**Project Developer**	**Capacity kW**	**Status**
Note: 1. wip - work in progress, 2. Gampolawalakanda - commissioned on 15 October 2004					

Table 61: Status of Grid Connected Projects Approved under RERED as at 30 September 2004[235]

[235] Status of Off-Grid Hydro Projects Approved under RERED as at 30 September 2004, online under: http://www.energyservices.lk [2005.11.17].

A.4.2 Status of Off-Grid Hydro Projects Approved under RERED as at 30 September 2004

Project Name	**Location**	**PCI**	**Project Developer**	**Number of Households**		**Installed Capacity in kW**	
				Plan	Actual	Plan	Actual
Hydro							
1. Eastern Horticulture	Mahiyanganaya	DFCC	Finconsult Global	86	wip	33.8	wip
2. Ohiya	Ohiya	HNB	BRITC	50	37	12.5	9.7
3. Polgaha Arawa	Meegahakiula	HNB	YEIC	46	47	9.0	7.0
4. Dehi Arawa	Bibile	HNB	ITS&C	42	wip	9.2	wip
5. Galwelagama	Madolsima	SEEDS	BRITC	60	wip	10.0	wip
Sub-Total Badulla District				284	84	74.5	16.7
1. Pelawadiya	Deniyaya	Non-PCI	CAPS	31	wip	7.0	wip
Sub-Total Galle District				31	0	7.0	0.0
1. Heeloya	Kandy	SEEDS	HEDO	60	60	12.0	13.0
Sub-Total Kandy District				60	60	12.0	13.0
1. Gonakapuella	Kitulgala	CBC	Sarath Chandrasena	37	35	8.8	8.0
2. Monera Ella	Yatiyanthota	DFCC	ERDCS	120	120	12.1	12.1
3. Thebuwatte	Kitulgala	DFCC	REDCO	85	wip	22.0	wip
4. Sekada Ella	Yatiyanthota	DFCC	CAPS	26	26	4.6	4.6
5. Aliyawetuna	Yatiyanthota	HNB	CAPS	58	58	11.0	11.0
6. Gigirandola	Yatiyanthota	HNB	CAPS	50	wip	18.0	wip
7. Kitulella	Yatiyanthota	HNB	CAPS	34	34	6.0	3.9
8. Samagi Dilena	Yatiyanthota	HNB	CAPS	78	78	12.0	10.0
9. Pallabage	Deraniyagala	HNB	BRITC	49	51	8.0	13.4
10. Us Ella	Deraniyagala	HNB	N Wimalaratne	50	50	10.0	10.0
11. Owala	Deraniyagala	HNB	Sumithuro	42	42	10.0	6.1
12. Diyakindure	Yatiyantota	HNB	CAPS	20	wip	6.0	wip
13. Elangapitiya	Aranayaka	HNB	ERDCS	40	35	7.0	6.9
14. Paraththawela	Yatiyantota	HNB	N Wimalaratne	50	wip	12.5	wip
15. Ihala Palanpitiya	Bulathkohupitiya	HNB	EACONS	60	wip	12.5	wip
16. Ihala Oluella	Yatiyanthota	HNB	CAPS	60	wip	12.0	wip
17. Higgasthenna	Theligama	SEEDS	CAPS	34	wip	7.0	wip
18. Ellapita Ella	Kegalle	SEEDS	HEDO	66	66	10.0	10.0

19. Alawattagama	Dehiowita	SEEDS	GPF	84	84	5.0	4.8
20. Sagara Wee Oya	Yatiyanthota	Non-PCI	CAPS	34	34	4.6	4.6
21. Wangedi Ella	Ruwanwella	Non-PCI	CAPS	18	wip	6.0	wip
22. Mandatula	Deraniyagala	Non-PCI	CAPS	8	wip	2.0	wip
23. New Polatagama	Yatiyantota	Non-PCI	CAPS	9	wip	2.7	wip
24. Salgala Ella	Ruwanwella	Non-PCI	CAPS	12	wip	4.0	wip
25. Daigala	Ruwanwella	Non-PCI	CAPS	33	wip	5.0	wip
26. Ballehela	Deraniyagala	Non-PCI	GPF	26	wip	8.0	wip
Sub-Total Kegalle District				1,230	713	248.8	105.4
1. Hellawatuna Ella	Pitabeddara	DFCC	LCDF	52	38	8.5	4.0
Sub-Total Matara District				52	38	8.5	4.0
1. Udawadiya	Badalkumbura	HNB	ITS&C	40	wip	11.0	wip
Sub-Total Moneragala District				40	0	11.0	-
1. Alu Oya	Ambagamuwa	HNB	GJMS Jayasekera	44	44	10.0	9.0
Sub-Total Nuwara Eliya District				44	44	10.0	9.0
1. Gallenakanda	Balangoda	DFCC	REDCO	45	wip	12.0	wip
2. Ura Oya	Balangoda	DFCC	TSDF	35	22	12.0	16.4
3. Kelikanda	Kolonna	DFCC	REDCO	65	65	16.0	16.9
4. Nahena	Kolonna	DFCC	REDCO	110	110	24.0	24.0
5. Kiula	Wijeriya	DFCC	REDCO	125	120	27.0	25.0
6. Welewatte	Kolonna	DFCC	REDCO	50	40	8.5	8.0
7. Rawanakanda	Balangoda	DFCC	ECS	47	25	8.5	7.1
8. Pahalathanabela	Kalawana	HNB	SPF	25	25	4.0	4.0
9. Wewagama Mahakumuradola	Kalawana	HNB	SPF	25	25	4.0	4.0
10. Wewagama Diyanagahahena Dola Sudeepa	Kalawana	HNB	SPF	29	29	4.0	4.0
11. Belihuloya	Ratnapura	HNB	ECS/Hettigoda	60	60	10.0	8.6
12. Gairaenagama	Ratnapura	HNB	Sumithuro	52	52	10.7	10.7
13. Gairaenagama	Ratnapura	HNB	Enexe	25	25	12.0	15.6
14. Athuraliya	Ratnapura	HNB	Sumithuro	68	68	20.0	20.0
15. Dothalu Oya	Gurubewilagama	HNB	Enexe	89	89	32.0	26.5

16. Suduheenkanda	Opanayaka	HNB	Enexe	14	13	5.0	4.5
17. Manamperigama (Palle Ella)	Godakawela	HNB	JDF	24	24	4.0	4.0
18. Andellawatte	Gurubewilagama	HNB	Enexe	24	25	11.5	11.5
19. Kaminidan	Wedamulla	HNB	UPDF	120	wip	23.0	wip
20. Kuttapitiya	Pelmadulla	HNB	GPF	43	35	8.0	7.2
21. Dumbara Manana	Ayagama	HNB	ECS/Udayaratne	94	78	21.2	19.2
22. Pussellakanda	Ayagama	HNB	SPF	22	22	6.6	4.1
23. Medaruppa	Hettikanada	SEEDS	GPF	21	wip	10.0	wip
24. Kosgulana	Kalawana	Non-PCI	Ranasinghe Electronics	15	18	8.3	10.0
25. Orupeellagama	Maliboda	Non-PCI	P G Ajith Kumara	36	35	20.0	20.0
26. Mapalana	Sripalabaddala	Non-PCI	CAPS	32	wip	12.0	wip
27. Sucharitha	Sripalabaddala	Non-PCI	CAPS	23	wip	7.0	wip
28. Pupulaketiya	Kolonne	Non-PCI	GPF	47	wip	10.0	wip
29. Hathbili Ella	Palmadulla	Non-PCI	SSA	15	10	5.0	6.9
30. Pelawatte Dola	Kalawana	Non-PCI	Suduwella Enterprises	30	wip	6.2	wip
31. Millaketiya Dola	Ayagama	Non-PCI	Surekuma	20	20	5.0	5.1
32. Anguruwela Dola	Ayagama	Non-PCI	K A N Kodituwakku	25	wip	8.8	wip
Sub-total Ratnapura District				1,455	1,035	376.3	283.3
Total Hydro				3,196	1,974	748.1	431.4
Wind				-	-	-	-
Bio-Mass				-	-	-	-
Total Off-Grid				3,196	1,374	748.1	431.4

Table 62: Status of Off-Grid Hydro Projects Approved under RERED as at 30 September 2004[236]

[236] *Status of Off-Grid Hydro Projects Approved under RERED as at 30 September 2004*, online under: http://www.energyservices.lk [2005.11.17].