# Grid Interconnection Mechanisms for Off-Grid Electricity Schemes in Sri Lanka

**Public Utilities Commission of Sri Lanka**

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## 1. Executive Summary

In early 1990's as about 75% of the people were living without electricity, the NGOs and private sector firms introduced stand-alone renewable energy technologies such as solar PV home systems and community based village micro-hydro power to cater to the electricity needs of the off-grid communities.

The Government of Sri Lanka (GOSL) in 1997 introduced a 5-year World Bank funded project named Energy Services Delivery Project (ESDP) to finance the off-grid schemes. The next phase of it was a 5-year project named Renewable Energy for Rural Economic Development (RERED) Project. In 2007, the government decided to extend the RERED Project by another 3 years and the World Bank financing scheme, finally ended in 2011. The total capacity of the off-grid renewable energy technology systems established is about 8 MW and these systems provided electricity to about 130,000 off-grid households. With the grid extension programs, the national electricity grid has reached 99 villages that were having micro-hydro power plants. When the grid is extended to the village, people tend to get grid connection, recognizing the comparative advantages of the national grid.

The Ceylon Electricity Board (CEB) has announced a list of villages that will not get grid access in the near future. The Ministry of Power and Energy has instructed the Sri Lanka Sustainable Energy Authority (SLSEA) to take necessary measures to provide off-grid renewable energy technologies to the villages in this list. In this context, there is an enabling environment created for establishing an appropriate mechanism for supplying off-grid energy technologies, to the communities who will remain off-grid. It is likely that the Solar PV will be the main off-grid energy technology that can cater to the electricity need of these off-grid households.

The government announced list of villages that will remain to be off-grid, does not include any of the present renewable energy powered villages. This implies that the grid will reach all off-grid villages that were having renewable energy schemes, in the near future. However, it is important to operate the existing off-grid systems, until the grid is extended to the village. Therefore, a special mobilization program is needed to build the capacity of the leaders of the Electricity Consumer Societies (ECS) to resolve issues they face at present to operate the power plants until the grid reaches the village. Such a program will make sure that the systems are functional and providing electricity to their members without any interruption.

Further, as the total capacity of the off-grid schemes is about 8 MW, it is important to explore the possibilities of integrating these stand-alone renewable energy schemes to the national grid when the grid is extended to the village. Recently, a pilot project was conducted to connect two village micro hydro power plants (10 & 20 kW) to the national grid. This pilot project has become instrumental in removing the technical, social, and legal barriers for grid interconnection.

The findings of the pilot project indicate that it is possible to connect these schemes to the national grid. It revealed that the fees charged by the CEB and SLSEA for grid connection is about half of the total micro hydro interconnection cost. Therefore, it is necessary to review these fees structure and try to reduce those, taking into account the capacity of the project.

When compared with the mini-hydro power, one of the main disadvantages of the micro-hydro power is the high operation and maintenance cost. The plant size is small however, it is necessary to have adequate staff for the Operation and Maintenance (O&M) of the power plant. It is recommended exploring the possibilities of using automatic synchronizing equipment for reducing the staff needed to operate the plant.

After about 6 months successful operation of the two pilot power plants, based on the outcomes, it is possible to identify whether the same Mini-Hydro tariff can be applied for the micro-hydro as well or need to introduce a new feed-in-tariff for micro-hydro on-grid schemes.

The primary data survey indicates that about 80% of all off-grid community based micro-hydro power plants are with capacities less than 10 kW. Therefore, it is important to conduct another pilot project for connecting less than 10 kW micro-hydro power plants to the national grid as single-phase power plants.

## 2. Objective

To recognize:

a) issues faced by off-grid electrification schemes in Sri Lanka
b) viable alternative interconnection mechanisms to improve financial viability and sustainability of off-grid schemes
c) interventions needed for sustainability of off-grid schemes covering all energy technologies (e.g. solar, biomass, wind and micro-hydro)

## 3. Methodology

Following are the steps taken to achieve the objectives of study:

I. Conducted a field research consisting of following components:
   a) Secondary data survey of the off-grid energy sector in Sri Lanka
      Reviewed and analysed the data from following sources:
      1. RERED Project reports and the data base
      2. Sri Lanka Sustainable Energy Authority database
      3. Energy Forum reports
      4. Federation of Electricity Consumer Societies database
   b) Review the present situation of the off-grid micro hydro schemes in Sri Lanka using a questionnaire (Annex 2) based primary data survey
      1. Mailed a survey form to 210 off-grid Electricity Consumer Societies to update its village hydro database
      2. 75 ECSs have returned the filled survey
      3. Combined the findings of primary data survey with a survey conducted in 2010

4. The database of micro-hydro power plants having access to national electricity grid was developed.

c) Review the performance of the two community-based micro-hydro grid interconnection pilot projects

II. Compiled the draft report based on the findings of the field research

III. Distributed the Draft report among selected 30 stakeholders for their comments. Final report was compiled based on the comments received. (See Annex-08)

## 4. An overview of the Off-grid Energy Sector in Sri Lanka

In early 1990's as about 75% of the people were living without electricity, the NGOs and private sector firms introduced stand-alone renewable energy technologies such as solar home systems and community based village micro-hydro power to cater to the electricity needs of the off-grid communities.

With the success of the efforts made by the private sector and NGOs, the government in 1997 introduced a 5-year World Bank funded project named Energy Services Delivery Project (ESDP) to finance the off-grid schemes and in 2002 extended it for another 5 years under Renewable Energy for Rural Economic Development (RERED) Project. In 2007, the government decided to extend the RERED Project by another 3 years. The World Bank financing scheme, finally ended in 2011. The total capacity of the off-grid renewable energy technology systems established is about 8 MW. These systems provided electricity to about 130,000 off-grid households.

The stakeholders in the off-grid renewable energy industry in Sri Lanka included: 9 - solar companies; 17 - equipment suppliers; 10 - village hydro scheme developers; 26 - independent consultants; 3 - NGOs; 9 - participatory credit institutions; 250 - electricity consumer societies; 2 - industrial associations; 1- umbrella organization of electricity consumer societies; and 4 - Provincial Councils. The status relating to the off-grid schemes is summarized in the table 1.

**Table 1: Status of off-grid energy technologies**

| Technology | Number of units installed | Capacity of a unit (kW) | Estimated total capacity (MW) | Number of households electrified | Number of units still in use (estimated) |
|---|---|---|---|---|---|
| Solar Home Systems (PV) | 120,000 | 0.03 -0.06 | 3.6 | 120,000 | 100,000 |
| Village Micro Hydro Power | 300 | 3 - 50 | 4.5 | 10,500 | 8,000 |
| Village Dendro Power | 11 | 10 - 30 | 0.1 | 100 | - |
| Wind Home Systems | 30 | 0.25 - 3.0 | 0.007 | 30 | - |
| Village Biogas Power | 10 | 0.30 - 2.0 | 0.006 | 30 | 2 |
| Pico Hydro Power | 40 | 0.30 - 1.5 | 0.012 | 40 | 40 |
| **Total** | | | **8.2** | **130,700** | |

About 3% of household were electrified through these off-grid systems. With the aggressive grid extension program of the government, the Ceylon Electricity Board connected 90% of Sri Lankan households to national grid by the end of year 2011. The balance 7% does not have access to modern electricity services at present.

The Government has plans to continue extending the national grid, to cover 96-97% of the population. It is not economically feasible to extend the grid to the rest due to geographical reasons. Hence, it is proposed to provide electricity to this balance 3-4% of the population from standalone off-grid technologies to achieve 100% electrification in 2013.

### 4.1 Solar Home Systems (SHS)

The Solar Home systems are domestic units and owned by individual users. The capacity of a solar home system is in the range of 30 W-60 W. The solar companies registered under the World Bank projects were selling Solar Home systems to the off-grid customers. Providing after sales services was also a responsibility of the solar company. A Solar Home System consists of a Solar Photo Voltaic (PV) Panel, controller, and a battery. The battery is charged using the Solar panel during the daytime. The battery is often used for lighting purposes using few DC bulbs during the night and for viewing a black and white TV.

By 2010, utilizing the World Bank funded projects the private sector managed to establish 120,000 solar home systems. According to the estimations made Ministry of Power and Energy, about 20,000 original users do not use of these units at present. The lending agencies informed that they have removed about 7000 units as the users failed to make the monthly payments on time. The other reason is when the grid is extended to the village, these SHS users tend to sell the unit to people living in other off-grid villages as a second-hand item.

The battery replacement cost is considered as the main constraint for sustainable use of solar home systems. A survey was conducted in 2005 by the RERED project to statistically establish the life of batteries installed under ESD and RERED Projects.[1] The survey revealed that the weighted average lifetime of replaced first battery was estimated as 30.4 months (2 1/2 years); 57% of the batteries surveyed were maintained at correct levels of water while 29% of the batteries were reported to be low in water level. Replacing the battery in every 2 1/2 years has become a burden to the consumer. The consumers in most instances fail to replace their batteries and therefore abandon the system.

In 2009, a physical assets verification survey was conducted for RERED Project covering 2000 Solar Home Systems.[2]
Primary data survey revealed following facts:

a) In general, 70% of verified consumers were satisfied with performance of their solar home system.
b) Eighty per cent (80%) of visited consumers complained about the lack of after sales services in their locality.

[1] SURVEY OF BATTERIES USED IN SOLAR HOME SYSTEMS IN SRI LANKA-RERED Project June – August, 2005
[2] Physical Verification of Assets (2007 & 2008) RERED Project – November, 2009

c) Few systems has been removed by the Participatory Credit Institution or sold to another person.
d) Significant number of beneficiaries does not have the Warranty Card, User Manual and Service Card of their systems. Most of them claimed that the Supplier did not hand over the documents when the system was installed.
e) Most of the beneficiaries were hardly aware of the consumer complaint procedure and the role of the Administrative Unit of the RERED Project.
f) It was found that some of the systems are used not only for domestic use but also for protecting their farming lands from wild elephants.

### 4.2 Village Micro-hydro Schemes

Standalone village micro-hydro schemes are owned by the Electricity Consumer Society (ECS). All electricity consumers in the village are members of the society. The micro-hydro system consists of a weir, channel, penstock, turbine, generator, control panel, and a mini grid. The village hydro scheme developers mobilize the community and assess the potential and micro-hydro equipment suppliers manufacture the turbine and generator.

At the development stage of a micro-hydro scheme, the communities faced following issues:
a) Lack of competence in social mobilization, designing the schemes and organizational development
b) Delays in getting clearances and approvals
c) Presence of dishonest developers (who sometimes would disappear after collecting an initial instalment from the community without completing work), and inability to take legal action against such fraudulence
d) Supplying sub-standard electro-mechanical equipment

The members pay a monthly fee to the society to cover the operation and maintenance cost of the plant. During the loan repayment period, the members repay the loan in instalments.

#### 4.2.1 Issues faced by the micro hydro schemes

a) Substandard machinery and equipment:
In most instances, there are no proper documents relating to specifications of the equipment and the name of the manufacturer of the equipment. The procurement of the equipment and its transactions were done without any written agreements. The suppliers do not provide necessary manuals and design diagrams to consumer societies with a proper certification. Furthermore, the warranty period of the equipment is not earmarked in a proper way and as a result, the societies have to pay extra charges for repairs and brake-downs.
b) Breakdown of communication between local community members and the equipment supplier
c) Lack of capacity of the ECSs on proper maintenance:
The operators are not adequately trained to attend to minor repairs. Hence, the society has to get the services of a technician at a very high cost to rectify even minor fault. People do not have electricity until the technician visit the village. This leads to dissatisfaction among consumers.

d) Members not attending the ECS meetings and failing to pay the monthly subscription
e) Formation of factions within the society leading towards disputes between members
f) Misuse of society funds
g) None availability of lightening arrestors
h) Need to replace wooden poles regularly

Many projects make use of wooden polls obtained from the surrounding areas for the distribution lines in order to minimize the initial costs that have to be borne. However, due to the life span of these wooden polls being limited to one or two years, much time, labour and money have to be spent on repairs and maintenance of the distribution lines. This has become a burden to the society and hence the quality of electricity supply has deteriorated rapidly.

### 4.2.2. Actions taken during this period to address the issues in the village micro-hydro sector

a) Recognizing importance of addressing the above mentioned issues the Federation of Electricity Consumer Societies (FECS) was formed in 2002 and through the FECS, the RERED Project, conducted number of capacity building programs. FECS now has a membership of 200 ECSs and it represents its member organizations at the national level forums, assists resolving social and technical issues of the schemes, and builds the capacity of the ECS leaders and power plant operators for sustainable functioning of the schemes.
b) The leaderships of electricity consumer societies were given a sound training in leadership, management, and accounting by the RERED project through the FECS. The FECS has conducted 18 capacity building workshops on leadership and operation & maintenance of power plants and trained 578 village leaders attached to 321 societies.
c) Because of the high costs involved in purchasing and transporting concrete polls to the remote villages, the FECS with the financial assistance of the Provincial Councils built the capacity of the communities to manufacture concrete poles locally. The Provincial Councils provided the 50% of the material needed to manufacture concrete poles. As a result number of societies replaced the wooden poles with concrete poles to ensure the sustainability of the schemes.
d) The Sri Lanka Standards Institute (SLS) with assistance of the Energy Forum established Code of Practice for Micro-hydro power in Sri Lanka. It is necessary to provide appropriate written information about the machinery - certify the equipment, publish technical manuals, service agreements.

## 4.3 Other technologies

### 4.3.1 Wind Home Systems

The wind system consists of a wind turbine located at a suitable place, a generator, invertor, and battery storage. The wind is however seasonal and site specific. Therefore, wind energy technologies cannot be used in isolation for off-grid use; it needs to be used as a hybrid system.

Wind-biogas and wind-solar hybrid systems were pilot tested during this period however, those proved to be costly and unaffordable to off-grid communities. Capital costs of these hybrid systems are high as there is a need to have two power plants for the two sources. Most of the off-grid wind systems were installed along the costal belt, where there were difficulties to maintain the systems. Due to these difficulties there are no wind power plants in operation at present. The lessons learnt indicate that wind technology cannot be used as an off-grid electricity generation technology.

### 4.3.2 Village Dendro Power

Village dendro power scheme consist of a wood gasifier, producer gas filters, an Internal Combustion engine running on producer gas, a control panel and a mini grid. The off-grid biomass projects were not successful due to technical issues and high costs involved with operation and maintenance of the plant. The communities were not in a position to meet the running cost. Further, the technology providers failed to resolve the issues associated with high tar-formation rate of the gasifiers.

The members have to provide wood to run the power plant periodically. There is no net cash gain for the farmers by selling wood. The income earned by selling wood is deducted from the electricity bill. As a result, there were number of social issues associated with collecting wood from the members. Due to these reasons, none of the off-grid dendro power plants is in operation at present.

### 4.3.3 Pico hydro power

Pico hydro systems are standard domestic units with less civil work in the range of 0.3-1.5 kW. Recently, Practical Action introduced a pico hydro system, but the affordability of the target consumers has become a barrier for wider application. There is no financing mechanism in place for pico hydro as it is similar to micro-hydro but smaller in size, which makes monitoring difficult.

### 4.3.4 Biogas Power

Biogas power unit includes a biogas unit, a filter, gas engine, and a mini-grid. This power generation technology was coupled with already existing biogas unit. Therefore, in the existing biogas schemes, one family owns the biogas unit whereas the generator and the mini grid is community owned. The potential for biogas power is limited as the potential for biogas production is limited as only a few off-grid households have cattle sheds. The farmers are reluctant to share cattle sheds due to cultural reasons, which makes community projects not practical. Hence, it is not possible to consider biogas power as a future off-grid power generating technology.

## 5. Future of off-grid renewable energy technologies

In the present context, the off-grid sector can be broadly classified into three groups:

- People not having access to any type of electricity
- People having off-grid energy technologies for electricity generation and will continue to be off-grid in the future as well, and
- People who originally had off-grid electricity but now having access to the national grid.

### 5.1 People not having access to any type of electricity

Government, until recently refrained from clearly demarcating the off-grid areas in Sri Lanka. The potential off-grid renewable energy users were reluctant to invest on an off-grid system; as if the grid is extended, the system they owned will be of no use. However the Ceylon Electricity Board for the first time in Sri Lanka announced a list of villages in August 2010 that will not get grid access in the near future (see table 2) and Ministry of Power and Energy has instructed the Sri Lanka Sustainable Energy Authority to take necessary measures to provide off-grid renewable energy technologies to those households.

**Table 2: CEB recognized off-grid villages**

| Province | No of Villages | No of Households |
|---|---|---|
| North Central Province | 12 | 185 |
| Northern Province | 37 | 3,133 |
| Eastern Province | 80 | 4,887 |
| Central Province | 26 | 2,924 |
| Western Province | 1 | 17 |
| Southern Province | 19 | 760 |
| Uva Province | 258 | 5,259 |
| North-western Province | 444 | 12,971 |
| Sabaragamuwa Province | 195 | 7,678 |
| **TOTAL** | **1072** | **37,814** |

Please refer Annex 3 for the CEB detailed list of off-grid villages.

The announcement of a list of off-grid villages by the government, created an enabling environment for the promotion of off-grid energy technologies. Under this favourable condition, there is a necessity to establish an appropriate mechanism for supplying off-grid energy technologies, to the communities who will remain off-grid. There are only two proven and well-established renewable energy technologies in Sri Lanka. Those are Solar PV and Micro-hydro. These remaining villages are located in the dry zone, having no micro-hydro potential. Hence, the main off-grid energy technology that can cater to the electricity need of the remaining households will be Solar PV.

### 5.2 People having off-grid energy technologies and will continue to be off-grid

The list of off-grid villages announced by the government does not include any of the community based renewable energy powered villages. However, there may Solar Home systems installed in some of households in those villages. Government will any way have a program for those villages and thereby the SHS users will be able to get a better after sales service for their systems as well.

There needs to be a special program to maintain the village micro hydro schemes until the grid is extended to the village. There is no enthusiasm among the members of the ECSs to spend money on the repair work, as they have to abandon the scheme when the grid

reaches the village. However if there is a firm program in place for grid connecting the micro-hydro schemes when the national grid is extended to the village, then there will be a motivation for villagers to look after their power plant until then. A special mobilization program is needed to build the capacity of the ECS leaders to resolve their issues until the grid is extended to the village.

### 5.3 People originally had off-grid electricity but now have access to the national grid

With the grid extension programs, the national electricity grid has reached 99 villages having community-based micro-hydro power plant (See Annex 4) and number of villages having Solar Home Systems. Fifty-two (52) of 99 micro hydro schemes are having capacities over 10 kW and the total capacity of these plants is 858 kW. The balance 47 schemes are less than 10 kW and the total capacity of those plants is 275 kW. As the CEB list of villages that will remain off-grid does not include any of the villages that are currently having community-based village micro-hydro schemes, it is likely that all the current micro-hydro villages will get access to national grid within next 2 years.

At present, the government has offered a cost reflective renewable energy power-purchasing tariff. Further, the government has introduced a Net-Metering Scheme for the grid-connected consumers allowing them to install their own renewable energy technologies.

Solar home systems of 30 W -60 W can generate only about 3-4 kWh/month. Even though the net metering facility is available, it is not financially viable to connect these SHS to the national grid using inverters and net-meters. However, the consumers can continue to use the solar PV system with the separate DC circuit (without connecting it to the national grid) and continue to get the benefit.

Developing interconnection mechanisms, for the micro-hydro schemes is useful to both the CEB and the community. These village schemes, due to its decentralized nature can boost up the voltage level in the villages and reduce the transmission and distribution losses. On the other hand, the community can sell electricity and get an additional income. Therefore, it was necessary to conduct pilot projects and check whether an appropriate power purchasing tariff should be introduced to connect these micro hydro plants to the national grid or not.

The Energy Forum (EF) together with the Federation of Electricity Consumer Societies (FECS) initiated a process in 2010 for grid interconnection, and connected two village micro hydro power plants to the national grid recently, and removed the technical, social and legal barriers for connecting the off-grid community based micro-hydro schemes to the national grid.

This process, on one hand will give an opportunity to get an additional income for the people living in those villages and on the other hand will create an enabling environment to add about 3 MW to the national grid. Further, this may encourage the on-grid villagers living in hilly areas to get together as cooperatives and tap the hydro potential in their villages to establish power plants and sell electricity to the national grid.

## 6. Issues associated with community-based micro-hydro power grid interconnection

Community based micro-hydro power plant was originally designed as an off-grid system. The capacity of the power plant, number of beneficiary families, getting clearances for the establishment of power plant from relevant government authorities were designed accordingly.

The mini-hydro power plants owned by the private sector followed a different path to sell electricity to the national grid. After the project developer completes the process of getting the 'Energy Permit' from the Sri Lanka Sustainable Energy Authority and Generation License from the Public Utilities Commission of Sri Lanka the CEB signs a power purchase agreement with the private developer for purchasing power from the mini-hydro power plant.

Connecting community-based micro-hydro schemes to the national grid was a new initiative and a series of initial discussions were conducted with key stakeholders for recognizing the issues associated with the grid interconnection of community based micro-hydro schemes. These issues can be broadly classified as technical, social, administrative and financial.

### 6.1 Technical issues

a) There are no technical standards established for connecting micro hydro power plants to the national grid.
b) There is a necessity to design a control system for micro hydro (less than 50 kW) grid interconnection as the existing control panels are for grid interconnection of higher capacity (above 200 kW) mini-hydro power plants. It is necessary to design a less expensive control panel for micro-hydro power.
c) There are no safety measures introduced for on grid micro hydro plants.

### 6.2 Social issues

As the off-grid micro-hydro power plant is owned by the Electricity Consumer Society (ECS) The electricity consumers become the members of the ECS. When the grid is extended to the village some households get grid connected and the rest, continue to get electricity from off-grid scheme. In this context there is an issue on the ownership of the plant. The on-grid people are not paying the monthly subscription fee as they do not get the electricity from the off-grid scheme at present. However as they have contributed to establish the power plant at the initial stage they too have a sense of ownership. Hence there is an uncertainty regarding the current ownership of the micro-hydro power plant. The people who are not yet connected to the grid are worried about their grid connect-ability. Due to these uncertainties, the members of Electricity Consumer Societies (ECS) do not trust each other and this has become an obstacle for initiating the grid interconnection process.

The Electricity Consumer Societies (ECS) are functioning as voluntary organizations and are registered at the Divisional Secretariat. Therefore these societies are not in a position to sign a power purchase agreement with the CEB as these are not recognized as commercial legal

entities. This has become another issue need to be resolved before connecting the power plant to the national grid.

### 6.3 Administrative issues

The mechanism for issuing Provisional Approvals and Energy Permits by the SLSEA is designed for new projects. The construction work of such projects starts only after getting the Energy Permit and signing the Power Purchase Agreement with the CEB. However the micro-hydro power plants are already commissioned and were in operation for number of years. The SLSEA approving process was originally designed for larger schemes and the fees charged for such projects are very high. It is necessary to simplify the Energy Permit issuing process for connecting the community-based micro-hydro power plant to the national grid.
There is also a difficulty for the micro-hydro power plants to meet the technical standards introduced by the CEB &PUCSL for the Mini hydro Generation License as the costs involved with meeting the technical standards is unaffordable to the smaller schemes. It is necessary for the PUCSL to take a decision on issuing a generation license to community-based village micro-hydro power plants with less stringent technical standards.

### 6.4 Financial issues

The community based systems are owned by the Electricity Consumer Societies. They faced hardship in getting approvals and constructing the scheme. All approvals were given taking into account the benefit the community get from the micro-hydro scheme. The only difficulty faced by the societies is they do not have adequate funds in their bank accounts for rehabilitation of the power plants and for meeting the costs involved with grid connection. Generally a renewable energy Power Purchase Agreement signed with the CEB by an investor is a bankable project. Micro hydro power plant is already established and operational. There is no risk involved with it. Hence it is possible to negotiate with banks and explore the possibilities of getting a loan to meeting the expenses relating to grid connection. The banks and other lending agencies are familiar with standalone micro-hydro schemes and grid connected mini-hydro power plants during the last 15 years. It is a well-known fact and there is no reason for the Banks not to finance micro-hydro grid connection projects after successful completion of the pilot projects.

In addition to the efforts of the communities the government provided subsidies to establish these stand-alone schemes with the intension of helping the people living in the village. It is necessary to block any efforts to be made by outside parties to get any indirect benefit from these government subsidies schemes. Further if a financing facility is available then there is no need to develop any other operational models and allow the outside parties to exploit the natural resources already developed by the people living the village.

## 7. Pilot project on micro-hydro grid interconnection

Two micro-hydro schemes (Athuraliya - 21 kW and Owala - 10 kW) were selected to pilot test the grid interconnection of the community-based micro-hydro power plants.

### 7.1 Activities conducted to overcome the technical issues

a) Discussions were conducted with technical consultants and the CEB to address the issues associated with micro-hydro grid interconnection.
b) Designed and produced the micro hydro grid connection controller panels
c) A CEB technical committee established standards for connecting micro hydro power plants to the Low Tension line with a dedicated feeder to the nearest transformer
d) CEB issued Technical Proposal for grid connection of the two pilot projects
e) CEB issued Grid connectivity proposal for the two pilot projects

### 7.2 Technical design for grid Connection

The induction generators in the village hydro schemes were connected to the grid by modifying the winding, IGC and adding necessary protection for main failure condition. Induction Generator in a village hydro scheme was used in 230 V Delta connection, therefore, the windings were rearranged in 400 V Delta or 400 V Star for the grid connected operation. The existing IGC was used to match the frequency before synchronizing and the acceleration power at the grid trip condition to avoid over speed. The Synchronizing Relay was introduced to monitor the grid and generator frequency and to adjust the generator frequency close to grid value by adjusting the IGC's operating point. Mains failure relay will detect mains failures and trip the contactor. (See Annex 5 for details)

### 7.3 Resolving social Issues for grid interconnection

The national grid was extended to the two selected villages recently. However there were 12 and 25 households in the two selected villages that were not connected to the national grid. Those people were not in a position to get the connection due to high connection costs as the houses located in remote corners of the village. As there was a necessity to connect these households to the grid, discussions were held with the Ministry of Power and Energy, and arrangements were made to get the financial contributions from the government to connect these households to the national grid.

Communities were mobilized to get-together for connecting the power plants to the national grid as there was confusion among villagers regarding the ownership of the power plant. Finally all the ECS members agreed to initiate a process for grid connection at a Special General Meeting.

The ownership of these two off-grid schemes was with the Electricity Consumer Societies (ECS) which were registered as welfare societies at the respective Divisional Secretariat offices. The ECSs partnered with FECS to raise capital for repair work of the power plants and for covering grid connected costs as the community could not raise the finances needed for the grid interconnection. A resolution was passed by the general membership to transform the ECS to new company and elect members for the Director Board of the new company to represent the members. Accordingly these two societies were transformed into two companies and were registered under the Company Act, to sign a power purchase agreement with the CEB.

### 7.4 Resolving administrative Issues for grid interconnection

A Board decision of the SLSEA was taken to extend the existing schemes to cover micro hydro plants as well. SLSEA issued the Energy permits to the two pilot projects after receiving the necessary documents from the newly formed community based companies.

List of the documents that were submitted along with application to the SLSEA:

a) Minutes of the general membership meeting of the ECS
b) Memorandum of Articles of the new Company
c) Company Certificate of Registration
d) Technical Proposal for Grid Connection
e) Copies of obtained approvals from various government agencies for the VHS

The PUCSL originally issued a "No Objection" letter to facilitate the process of grid interconnection of the two pilot projects and then issued Licenses for two on-grid micro-hydro pilot projects.

### 7.5 Financial mechanisms for grid interconnection

The financing for the two pilot projects were provided by the Federation of Electricity Consumer Societies. The two Power Purchase Agreements signed under the existing mini-hydro (local) feed-in-tariff.

### 7.6 Performance of the pilot on-grid micro-hydro pilot projects

**Table 3: Profile of the selected pilot projects**

| Description | Athuraliya | Owala |
|---|---|---|
| Name of the Project | Kaduruwana Dola Aturaliya Micro-hydro Project | Malpel Dola Owala Micro-hydro Project |
| Name of the Company | Aturaliya Ekamuthu Grameeya Jalaviduli Paribogika Samagama (Registration No.: PB 4792) | OwalaSamagi Grameeya Jalaviduli Paribogika Samagama (Registration No.: PB 4791) |
| Village | Athuraliya | Owala |
| Grama Niladhari Division | Gilimale South | Heenberenduwa |
| DS Division | Ratnapura | Ratnapura |
| District | Ratnapura | Ratnapura |
| Power plant capacity | 18 kW | 12 kW |
| Plant Factor | 80% | 80% |
| Estimated Annual Electricity Generation | 0.126 GWh | 0.084 GWh |

| Description | Athuraliya | Owala |
|---|---|---|
| Total Households | 68 | 62 |
| Houses without electricity when the grid connection started | 25 | 12 |
| Distance to grid (m) | 500 | 500 |
| Commissioned on | 9/20/2004 | 4/4/2004 |

**Financial Analysis of the two pilot projects**

**Table 4: Capital costs of the pilot project**

| | Athuraliya | | Owala | |
|---|---|---|---|---|
| | **Off-grid costs (Rs)** | **On-grid total costs (Rs)** | **Off-grid costs (Rs)** | **On-grid total costs (Rs)** |
| **Off-grid Micro hydro Approvals** | **100,000** | **100,000** | **100,000** | **100,000** |
| **Grid connection approvals** | | | | |
| Company Registration | | 56,710 | | 56,710 |
| SEA Application | | 100,000 | | 100,000 |
| SEA Energy Permit | | 10,500 | | 6,000 |
| CEB Application | | 1,000 | | 1,000 |
| CEB – LOI | | 100,000 | | 100,000 |
| CEB – SPPA | | 25,000 | | 25,000 |
| PUCSL – License | | 10,000 | | 10,000 |
| Administrative Expenses for grid connection | | 194,550 | | 194,550 |
| Civil Works (depreciation 5% / y) | 755,000 | 527,245 | 580,000 | 405,036 |
| Machinery & Equipment (depreciation 10% per year) | 600,000 | 426,878 | 525,000 | 650,106 |
| Interconnection | | 931,500 | | 877,500 |
| Commissioning fee- free for the pilot project | | 125,000 | | 125,000 |
| Grid extension costs (Ministry of Power and Energy contribution) | | 500,000 | | 1,500,000 |
| **Grand Total** | | 3,108,383 | | 4,150,902 |
| **Cost per 1 MW** | | **172,687,933** | | **345,908,459** |

**Operation and Maintenance Costs**

| | |
|---|---|
| Total cost per year | 675,000 |
| O&M as a % of capital - Athuraliya- 18 kW | 27% |
| O&M as a % of capital - Owala - 12 kW | 27% |
| Unit selling price (Rs/kWh) - 2011 rate | 13.32 |
| Estimated annual revenue - Athuraliya (Rs) | 1,680,238 |
| Estimated annual revenue - Owala (Rs) | 1,120,159 |

(See Annex 6 for details)

## 8. Recommendations

### 8. 1. Providing standalone renewable energy technologies to off-grid communities

As the World Bank funded projects (ESDP & REREDP) which were in operation for 13 years ended in 2011, there is no mechanism in place at present for financing and for providing technical assistance for the off-grid communities. Hence a cabinet decision (Cabinet Memo No. 19/2011/PE dated 31 March 2011), was taken to provide a grant of Rs 10,000 or Rs. 30,000 per household for getting an off-grid system. Further, the government has decided to use the Samurdhi Bank network to disburse grants and loans to the targeted beneficiary families. However, the SLSEA is yet to establish a mechanism for providing off-grid technologies to the target groups. It is important to establish an appropriate mechanism to obtain the necessary approvals from the CEB and the SLSEA within a short period as it takes more than 12 months to get the approvals at present.

### 8. 2 Sustaining the stand alone systems that is going to be remain as off-grid

#### 8.2.1 Sustainability of the existing village micro-hydro schemes

There are no micro hydro schemes installed in any of the villages listed to be remained as off-grid and therefore the national grid will reach all micro-hydro in the future. However, there needs to be a special program to maintain the remaining village micro hydro schemes until the grid is extended to the village.

a) The ECS leaders frequently get changed and therefore it is necessary to conduct capacity building programs to train new ECS office bearers and operators at least in every 3 years' time.

The RERED project which supported the FECS to conduct the capacity-building program ended, and there is no agency to support FECS to conduct these programs at present. The FECS has frequent requested from Sri Lanka Sustainable Energy Authority to provide financial support for these programs without any success. As there is no government agency to look after these schemes the PUCSL can play a role by providing financial assistance to FECS to conduct these capacity building programs regularly, to protect the electricity consumer rights of these people living in remote villages.

This capacity-building program should target the society leaders and the operators of the power plants. The program should create awareness among the society leaders on leadership & leadership qualities. Further, the leaders should be trained on basics of accounting, book keeping, and preparation of financial statements.

The village hydro operators should be trained on basic power scheme Items identification; daily operational items identification; maintenance, trouble shooting and rectifications; electrical quality monitoring and testing, safety systems and precautions; log-book recording and introduction to guide book.

b) Identify local technicians such as technicians repairing TV/ Radio- electronic items, electricians, lathe man, etc. mainly at District level and in some areas at Divisional level to repair equipment and develop them as on call repairing centres.
c) As the maintenance cost of electrical equipment rises societies are finding it difficult to meet the repair and replacement costs. It is important to have a government subsidy through Samurdhi Banks to Samurdhi beneficiary (who have ECS membership) to partially support the maintenance work of these micro-hydro schemes.
d) The catchment areas of the micro-hydro power plants are seriously affected by human activity the water scarcity issues emerge. Therefore steps should be taken to draw the attention of authorities and officials in state and non-governmental institutions towards extending the necessary co-operation to the societies to protect the catchment areas of the micro-hydro schemes.
e) In the case of off-grid energy technologies, as there is no opportunity to increase the capacity of the power plant, the problems related to increasing electricity consumption needs of the consumers can only be addressed through energy efficiency measures. An awareness campaign on energy efficient appliances, need to be designed and conducted to address this issue.

### 8.2.2 Sustainability of Solar PV home systems

Some of the households in villages listed as off-grid by the government may have Solar Home systems. The existing SHS users are faced with an issue of not having proper aftersales services for their PV systems. Further low income SHS users are finding it difficult to meet the battery replacement costs. If the Government introduces a program for those villages then the current SHS users too will also be able to get a better aftersales service for their systems.

**a)** A mechanism should be established for providing items to be replaced. There should be skilled personnel for repair work. This service cannot be expected from the solar companies as they do not have networks due absence of a stable market for SHS at present.
b) The solar companies should either provide long lasting batteries with the systems or an appropriate maintenance subsidy should be established by the government for the Samurdhi beneficiaries (who have solar home systems) similar to the kerosene subsidy to support replacing batteries of their solar home systems.

### 8.3 Grid interconnection of off-grid power plants

It is unlikely that the Solar Home systems can be grid connected as the systems are very small in size (30-60 W). Instead these systems can continue to be used as stand-alone schemes in the future as well. Hence grid interconnection is possible only for micro-hydro power plants. The pilot project for connecting two micro hydro plants - 10 kW and 20 kW was successful and the grid interconnection can be done for other micro-hydro power plants as well. As all existing community-based micro-hydro power plants are with a capacity less than 50 kW, and as the distribution transformer capacity is 100 kVA, there will be no technical limitation for grid interconnection.

### 8.3.1 Requirements for a micro hydro power plant to be grid connected

The micro-hydro plants having capacities less than 10 kW are not financially viable as the per unit grid connection cost is very high.

The lessons learnt from the two pilot projects indicate that the micro-hydro projects should satisfy following conditions to get the grid interconnection:

- Capacity should be more than 10 kW
- Should have all the approvals from government agencies as an off grid scheme
- The distance between the national grid and power house should be less than 1.5 km
- Civil constructions and electro-mechanical components should be at an acceptable level or should be generate additional funds to refurbish electro-mechanical equipment and repair civil works.
- Should have the consent of consumers to connect the plant to the national grid
- Funding should be available to connect remaining (if any) households to the national grid
- The ECS should have the ability to generate adequate funds for grid connection

### 8.3.2 Process for connecting community based village micro-hydro power plants to the national grid

Following steps should be followed while connecting the community based village micro-hydro power plants to the national grid:

**Step 1: Company Formation**

The ownership of current off-grid schemes is with the Electricity Consumer Societies (ECS) which is registered as welfare society under the particular Divisional Secretariat office. Since the Electricity Consumer Societies (ECS) are community driven and members of the ECS will not be able to make sure the ownership as a “Viable Business Unit”. Community should be mobilized to avoid creating disputes among villagers while connecting these schemes to the national grid. Consensus among the ECS members for grid connection needs to be reached at a Special General Meeting (SGM) of the society. A resolution should be passed at the SGM to transform the ECS to new company and elect members for the Director Board of the new company to represent the members. The new company should be registered under the Company Act, to sign a power purchase agreement with the CEB.

**Step 2: Electrifying remaining households**

It is necessary to ensure that all households are get connected to the grid and accordingly after conducting the discussions with the Ministry of Power and Energy and the CEB arrangements should be made to get the financial contributions from the government to extend the grid to the remaining households of the micro-hydro village which did not have access to the national grid. If not it is necessary to explore the other means of getting financial assistance to extend the grid. Otherwise the grid extension

cost of remaining households needs to be internalized while fixing the micro-hydro feed-in-tariff.

**Step 3: Assessment the community share**

The Federation of Electricity Consumer Societies with the experience gained through the two pilot projects implemented should help the company to prepare an initial balance sheet of the Company including the leasehold right, plant and machinery, bank loans, any outstanding Bills etc. The expected outcome of this initial balance sheet is to quantify the value of the Equity, which is basically the value representing the contribution made by the members in cash or in labour. Now the equity capital is belongs to the ECS.

**Step 4: Approvals from Sri Lanka Sustainable Energy Authority (SLSEA) and Ceylon Electricity Board (CEB)**

The next step is to apply for Provisional Approval (PA) and Energy Permit (EP) from Sri Lanka Sustainable Energy Authority (SLSEA). The SLSEA has already taken decision to combine the standard two stage process of issuing a PA first and then issuing an EP to a single step as the plants are already established and commissioned. In this context it is easy for the company to submit all documents to SLSEA get the Energy Permit. Further the company can apply for LOI from CEB at the same time.

**Step5: Capital for grid interconnection**

For raising funds for the repair work of the power plant and grid interconnection, the members of the society should be encouraged to get additional shares of the company by further investing on the project. If the community cannot raise the finances needed for the grid on their own, then the newly formed company can either to get a loan from a Bank or to get partnered with outside parties to raise balance finances for the project. This should be done while ensuring a reasonable share of equity to the members of the society.

When there is an equity share capital in the Company there are plenty of options available for consideration (basically play with that) to ensure the going concern of the Company. ECS can appoint Board of Directors and mange that as a business. A dividend policy may be declared in view of securing the long-term equity participation by the members. If necessary ECS members can either sell their shares, to the other members of the company or any other party with consent of the company.

**Step 6: Clear ownership of the assets**

One of the fundamental requirements for business is to ensure the ownership of the assets. There may be some assets used by the ECS however the ownership may not yet been secured. For an example, the land which the plant located may not be owned by the ECS. In such a situation demarcation of the boundaries of the land in which the plant

is located and an access road/path to the power plant is necessary. As some important legal provisions are given in State Land Ordinance, i.e water stream and land reservations in both sides should not be treated as a private property, it is necessary to get assistance from the Divisional Secretary, or Grama Niladari, to get the ownership cleared. In this context it is necessary to get a survey plan prepared by a licensed Survey and sign a lease agreement between the owners of the land most probably the State represented by the Divisional Secretary (Ds) and the newly incorporated company. Such agreement should ensure that the land could be used only for the generation of electricity. All other activities should be treated as restricted activities and should not be allowed without prior approval from the DS.

**Step 7: Signing the Power Purchase Agreement**

Sign a SPPA with CEB and sell the electricity at the rate determined by the Commission in NCRE tariffs.

At present the Government of Sri Lanka has offered a cost-reflective technology-specific renewable energy feed-in-tariff. Further, the government has also introduced a Net-Metering Scheme for the grid connected consumers to have their own on-grid renewable energy systems.

The net-metering facility cannot be adopted for the community-based micro-hydro power plants as the grid connection of the power plant will be done at one point and the grid connection of the consumers will done at number of other points. Further as the consumption of the consumers of the ECS are low there will be a net power export by the end of every month, for which there is no payment scheme under the net metering facility. Hence it is not recommended to connect the community based micro-hydro schemes under net-metering facility.

After 6 months of successful operation of the two pilot projects, it is necessary to review the situation and conduct a financial analysis, and recommend the relevant authorities whether to extend the mini hydro (local) feed-in-tariff to cover on-grid micro hydro plants or to introduce a new tariff to ensure the financial sustainability of the on-grid micro-hydro schemes.

### 8.3.3 Explore the possibilities of reducing the capital costs of micro-hydro grid interconnection

The cost of grid interconnection includes following:

1. SLSEA Application fee : Rs. 100,000
2. CEB Letter-Of-Intend (LOI) : Rs. 100,000
3. Installing the meters : Rs. 110,000
4. Dedicated cable line up to the transformer : Rs. 550,000

As the total cost of the interconnection is about Rs. 1.6 million (without the cost of grid extension of balance households), it is important to explore whether it is possible to reduce

the above mentioned fees which is about half of the total interconnection costs. The first two fees are standard rates charged by the SLSEA and CEB. This rate is the same for all plants in the range of 10 kW and 10 MW. It is appropriate to discuss with the relevant institutes and see whether any concession can be given to micro-hydro projects to make them financially attractive for grid connection. It is recommended having a rate of 1000 Rs/kW for both SLSEA application fee and for LOI (CEB) for power plants having less than 100 kW.

The electricity measuring meter for micro-hydro power plant is installed by the CEB Meter Lab located in Colombo. This is the general procedure adopted by the CEB for the mini-hydro projects and as it is handled from the Colombo the installation costs are high. On the other hand as the bulk supply meters are generally installed at the Area Engineer level it is necessary to explore whether these micro-hydro meters can be installed by Area Engineer or not, as it will drastically reduce the cost of installation of the meter.

The CEB highlighted the importance of having a dedicated cable from the power plant to the transformer for the two pilot projects due to safety reasons. If the connection can be made closer to the power house then there is possibility of reducing the cable costs. As this option is already available for net-metering facility it is important to explore whether there is a possibility of connecting the micro-hydro plants to the nearest 3 -phase line. This will contribute to reduce the cost of micro-hydro grid interconnection.

#### 8.3.4 Explore the possibilities of reducing the O&M costs of grid connected micro-hydro power plants

The main disadvantage of the micro-hydro power when compared with the mini-hydro power is the high O&M cost. The plant size is small; still it is necessary to have adequate staff for operation and maintenance of the power plant.

As these plants are located in remote villages the national grid failures and voltage fluctuations occur frequently. The switchgear of this pilot project did not include automatic synchronizing equipment. When the grid trips, the operator needs to re-energize it and synchronize it. As a result it is necessary to have a full-time (24 x 7) operator for the power plant. Instead if this can be done using an automatic synchronizing equipment then the staff needed to operate the plant can be reduced.

#### 8.3.5 Connecting less than 10 kW capacity power plants to the national grid

The primary data survey indicates that about 80% of all off-grid community based micro-hydro power plants are with capacities less than 10 kW. The lessons learnt from the pilot project indicate that connecting less than 10 kW micro-hydro power plants to the national grid in not financially feasible due to high upfront costs of grid interconnection. One way to reduce the grid interconnection cost is to connect these plants not as a 3 phase supply but as a single phase supply. The CEB is already connecting less 10 kW power plants to the national grid under the net-metering scheme. The same techniques can be used to connect the micro hydro power plants to the national grid as well. We believe it is worth conducting

another pilot project and see whether single phase power plants can be connected to the national grid without burdening the CEB or not.

### 8.3.6 Establishing a Lending Mechanism for grid interconnect

Introducing a lending mechanism for micro-hydro grid interconnection may need some time, as it is necessary to see how the pilot plants perform in the long-run. The best way is to allow the pilot plants to run for about 6 months, monitor the performance of the plants, compile case study reports, select few banks and then initiate discussions with them to introduce a lending mechanism for the communities to connect their power plants to the national grid.

**Annex 1: Development of the off-grid sector in Sri Lanka**

**Annex 2: Survey Form used for primary data survey**

**Annex 3: The CEB list of villages that will remain off-grid**

**Annex 4: Database of off-grid micro-hydro schemes having access to national grid**

**Annex 5: Technical design for grid Connection**

**Annex 6: Financial Analysis of the two pilot projects**

**Annex 7: Full database of the micro hydro schemes in Sri Lanka**