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Small Hydropower Plants

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SMALL HYDROPOWER FOR DEVELOPING COUNTRIES:
THE ROLE OF UNIDO*

Prepared by

the UNIDO Secretariat

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1. Introduction

The availability of reliable and economic energy is one of the important prerequisites for economic and social development. The persistent energy deficiency and corresponding low social and economic status of developing countries is demonstrated by the low per capita consumption of commercial energy of around 25 GJ compared to around 200 GJ in industrialized countries. Even more alarming is the urban-rural disparity in energy consumption and the corresponding level of economic activities taking into account that 70 per cent of the total population in developing countries is living in rural areas. There is an ever increasing contrast between the dispersed energy demand of the urban and industrial centres and the surpressed energy demand in rural areas depending almost entirely on non-commercial energy supply in particular fuelwood. With growing needs due to an expanding population the energy sources are becoming progressively depleted thus leading not only to local shortage but also to ecological damage through deforestation, soil erosion and loss of nutrients. The availability of commercial energy not only remedies the situation but also offers the means of moving away from the subsistance economy and encouraging local economic development.

Commercial energy resource development is therefore at the core of the general development problems of the rural areas in developing countries and the availability of electricity is a major strategic element in promoting the creation of rural industries as a basis for local economic opportunities and improved living conditions. For the foreseeable future, however, it will not be possible to satisfy the energy demand of remote rural areas with oil or connecting them to the electric network in order to meet the basic needs of the people and to support any form of economic growth.

In rural areas of developing countries it would therefore seem most appropriate to develop small indigenous energy resources particularly new and renewable ones with the most suitable local inputs and technologies taking into account the existing technical skills and local environmental and social conditions. This is even more important for rural electricity supply which today to a large extent is based on diesel generators using imported fuel. However, technologies exist or are being developed for electricity generation from indigenous renewable resources. They range from biogas systems and gas from agricultural wastes, through wind turbines and small hydropower plants, to more complex systems based on solar energy conversion, including photovoltaics.

In this context it is interesting to note that hydropower not only accounts for the major part of the present worldwide renewable energy supply but it also represents a promising energy source for many developing countries for decades to come. Its development, however, is strictly site-dependent and therefore feasible only in specific locations where the electricity can be economically transmitted to the consumption centres.

While very little data is readily available the installed capacity of small-scale hydropower plants has increased indicating a growing interest in its development. Although the economy of small-scale hydropower projects is in general unfavourable among others on account of high per unit generation costs these projects offer certain other advantages such as the possibility to implement the projects with locally available technical, industrial and financial resources.

Small hydropower projects, based on the use of decentralized technologies and the unpackaging of projects, taking into account that civil works may claim up to 50 per cent of the total project costs, are favouring the creation of domestic technological capabilities and are stimulating small scale manufacturing industry. Both the pre-investment and the investment effort involved in the establishment of a small hydropower plant will be large in comparison to the alternative solutions but this is compensated for by the technical simplicity of the concept, very low operating costs, high energy conversion efficiency and a long asset life. The complexity of the pre-investment work coupled with the capital-intensive nature of the projects will make it necessary for most developing countries to seek international assistance for project development and implementation and for training of national personnel in this work.

The steady rise of interest and activities in small hydropower plants is also demonstrated by the ever increasing number of reports, articles and publications of national and international organizations covering all aspects of the application and local manufacturing of small hydropower plants for rural development in development countries. Important UNIDO and a selection of external publications are listed in Attachment I.

At the fourth General Conference of UNIDO (UNIDO IV) in 1984 assistance in the development of the capacity and infrastructure for reliable and econonic energy supply both for agricultural development and industrialization in rural areas in developing countries was laid down as one of the priority areas for UNIDO's activities.

In particular at UNIDO IV it was stressed that due attention should be paid to the:

- promotion of small hydropower;
- co-operation among developing countries covering all aspects related to energy and industrialization;
- development of local manufacturing capacities and capabilities for capital goods manufacture and services for the energy sector.

The above mentioned recommendations are a continuation as well as verification of UNIDO's small hydropower programme established in the late 1970s. It was initiatied in 1979 with study tours to China, where more than 60.000 small hydropower plants had been installed by 1980 with a total capacitiy of around 7 GW(e), and seminars and workshops on the exchange of experience and technology transfer on mini-hydro electric generation units in

Nepal and the Philippines. The small hydropower programme was further expanded with the Regional Network for Small Hydropower for Asia and the Pacific in 1982 and the inititiatives for interregional co-operation for the small hydropower development between Latin America and the Arab countries in 1985 as well as the organization of several regional training workshops on small hydropower. In co-operation with OLADE and Chinese experts the present knowledge on small hydropower was and will be presented in a series of manuals and reports for the exchange of experience and technology transfer.

As a reflection on the recommendations of UNIDO IV the present UNIDO technical co-operation projects directly related to small hydropower plants are:

- feasibility studies, planning and integration of small hydropower into rural industrial development, especially with rural industries;
- review of suitable designs, technological development and construction practice of small hydropower;
- promotion of the indigenous manufacture of small hydropower equipments through the concept of technology unpackaging and standardization of design;
- support for regional co-operation and exchange of technical information in particular among developing countries;
- co-operation between institutions and countries engaged in small hydropower development;
- training of project and exploitation personnel.

The concept of technology unpackaging was deliberated in depth at the second UNIDO consultation on Capital Goods Industry with Special Emphasis on Energy-related Technology and Equipment in Stockholm/Sweden, June 1985. As an immediate follow-up of the Stockholm consultation and in accordance with the increasing interest of developing countries UNIDO has selected the small hydropower field for promotion of technology unpackaging through international and regional co-operation measures.

The present expert group meeting on standardized small hydropower plants is a first step in this direction assessing a number of standard small hydropower designs and select those that have potential to maximize the use of local human and material resources in their implementation.

In accordance with the objectives of the meeting the paper presents general aspects of UNIDO's mandate to assist developing countries in their decision making process for an economic and reliable use of small hydropower plants in particular on problems related to the local manufacturing of equipments. Important aspects are resource estimation, programme justifications through energy demand and supply analysis and planning, selection and implementation of energy technologies and the establishment of the technical capabilities and infrastructures for local manufacturing and technology unpackaging.

2. The case of small hydropower plants

Under the collective name "Small hydropower" UNIDO is using the following classification:

- Small Hydropower Plants: 2,001 to 10,000 kW(el);
- Mini Hydropower Plants: 101 to 2,000 kW(el);
- Micro Hydropower Plants: up to 100 kW(el).

This classification is based on the size and complexity of the involved structure, the degree of specific site engineering and investigation, on the degree of standardization of the equipment design and the end use of the electricity produced.

Small hydropower plants are fairly sophisticated installations and in some cases based on equipments of standardized designs. They require relatively large complex structures, including dams, powerhouses and penstocks. These installations would normally be tied to a grid distribution system, either local or national.

Mini hydropower plants are much simpler installations. Small diversing weirs rather than dams are utilized similar to small canal structures. The penstocks are simple and constructed from locally available materials and the powerhouses resemble in most of the cases pumphouses. Standardized designs exist for all or most equipments although not always used by the developing countries. A typical installation may initially serve one or more isolated small communities, but may later be tied to a larger grid system.

Micro hydropower plants are small mini-hydro plants which serve individual small industries or several families. The turbines normally are of very simple design, e.g. Banki-Mitchel, centrifugal pumps operated in reverse, etc..

In some cases the whole micro-hydro installation may be constructed as "packaged" transportable hydroelectric unit, normally rated for rural applications within the range between 0.5 and 15 kW(el).

Due to the economy of scale with hydropower as with most energy technologies a considerable cost difference exists between the lower end of "micro" range and the upper end of the "small" units.

Consequently investment criteria, technical complexity and organizational approach for the installation and operation differ significantly across the range. In general the smaller the hydropower plant the less the planning that is needed and the smaller the environmental impact.

However, in each case some planning is required including hydro resource assessment through hydrological and topographic studies, electricity demand and cost-benefit analysis, local contributions and investment planning.

Some of the aspects needed for planning and decision making are summarized in the following chapters.

2.1. Small hydropower resources

Presently, hydropower provides worldwide about 6 per cent of the total primary energy consumption. However, only about 16 per cent of the total technically useable hydro potential in Asia and about 13 per cent of the corresponding potential in South America have so far been harnessed. For Africa, the corresponding proportion is only 4 per cent compared to Europe where around 94 per cent of the potential has already been harnessed.

As the potential of small hydropower is influenced by local geographical and climatic factors its assessment is difficult. Table 1 presents the results of the 1986 survey of the World Energy Conference of exploitable capabilities, operational and planned capacities of small hydropower schemes in those developing countries where information is available. Out of the total of 18 presented countries only seven countries provided information on exploitable capabilities . Detailed information is available in the People's Republic of China with a theoretical potential of small hydropower of around 150 GW and an exploitable potential of 70 GW with an annual potential electricity generation range of 200-250 TWh (total 1985 electricity production in China: 400 TWh).

Table 1: Survey of exploitable capabilities, operational and planned capacities of small hydropower schemes (installed capacity less than 1 Mw) in some developing countries.

Country name	Year of Refer.	Exploitable Cabability* (GWh)	Capacity Operational (MW)	Planned (MW)
Argentina	1984	38	7	11
Burundi	1984	U	3	0.86
China	1984	210,000	9,060	71.300**
Cyprus	1982	23,500	0,65	0.9
Indonesia	1984	U	15.64	U
Jamaica	1984	U	0	2.5
Jordan	1984	14	U	U
Korea (Republic of)	1984	U	1.85	17.85
Malaysia Sarawak	1984	U	3.22	27.11
Mexico	1984	U	69.4	U
Nepal	1983	U	U	1.27
Philippines	1984	U	1.2	U
Portugal	1984	15,000	-	6,000
Sri Lanka	1984	263	1	3.5
Taiwan	1984	U	3.3	10.6
Thailand	1984	U	2.846	20.893
Venezuela	1984	U	23.31	0.415
Zambia	1984	8.76	0.75	0

Source: World Energy Conference, Survey of energy resources 1986.

Note* : Exploitable capability for small hydro power schemes is the total annual energy which could be exploited for small scale hydro plants within the limits of current technology and under present and expected local economic conditions.

Note **: Exploitable capacity

U: Denotes unavailability of information.

Consequently individual small hydropower projects must start with a resource estimation of prospective sites based on hydrological surveys of the power generating capacity and of the potential energy output which depend primarily on the magnitude and distribution of the flow and head.

Two types of basic data are required to estimate the capacity and energy output of hydropower site:

1. Topographic data to determine the avilable head;
2. Hydrologic data to determine the available discharge.

The topographic data are necessary to work out the plant layout in particular the gross head for the given flow conditions and the type of the plant.

The hydrologic data are important for economic operation of the plant but are often not easy to obtain.

A first step in conducting hydrologic surveys is the determination of the average monthly stream flow for a given location on the river and for the longest possible period. The principle determining factors are basin precipitation and catchment area. The average monthly flow can be estimated from the precipitation records or by some empirical formulas.

The second aspect of the hydrologic study is the determination of flood volumes, peak discharges, and their frequency of occurrence. From these data the safe water bypass of flood flows can be designed. Another requirement is to determine the tailwater curve for the dam (if needed) and to set the elevation of the generator floor as well as to assess the integrity of the intake structures during the passage of large floods.

There are two methods to calculate the power output and annual energy production of small hydropower plants:

(i) the flow-duration curve method;
(ii) operational study modelled with a help of computer.

The flow-duration curve is an excellent tool for use in appraisal studies, but not precise enough for feasibilities studies. For the operational study a cycle covering at least the last ten years should be modelled in order to reasonable estimate the annual energy output.

This information is primarily needed for small and to the lesser extent for the mini hydropower plants. As the micro schemes in most of the cases are constructed by the local community a full streched survey may be unaffordable. Simpler methods for data collection seem to be sufficient.

2.2. Electricity demand for rural development

Rural electrification aims at providing electricity to areas with low present demand and dispersed potential consumers. Availability of electricity provides both direct benefits to the rural households, agriculture and industry, e.g. improved health care, reduced illiteracy through access to communication media, improved irrigation of the arable land, industrialization opportunities, etc., and indirect benefits in terms of improvement of the labour and of the environmental conditions, social and demographic stability, etc.. Table 2 shows as an example a selection of agro-industrial activities and the amount of electricity required for daily production.

Table 2: Electricity demand for selected agro-industrial activities.

Industry	Power Station Rating	Daily Consumption
Sawmill	30 - 60 kW	120 - 240 kWh
Carpentry	3 - 15 kW	15 - 75 kWh
Sugar Refinery	10 - 20 kW	50 - 100 kWh
Flour Mill	3 - 20 kW	18 - 50 kWh
Spinning Mill	2 - 6 kW	10 - 30 kWh
Coffee Processing	5 - 30 kW	35 - 210 kWh
Quarrying	6 - 30 kW	30 - 150 kWh
Ice Manufacture	6 - 60 kW	50 - 500 kWh
Slaughter-house	5 - 10 kW	25 - 50 kWh
Tile Factory	2 - 12 kW	12 - 75 kWh
Water Pumping	2 - 100 kW	8 - 400 kWh

Electricity can be supplied to rural areas by reginal or national grid distribution system or by local decentralized power generating units, e.g. diesel or producer gas generators, small hydropower plants, photovoltaic arrays, wind generators, etc.. The cost of electricity supplied to the end users varies substantially from individual cases and is a function of generation mode, transmission distances and of electricity load density.

The distinction and choice between centralized and decentralized supply systems, however, is not a simple problem. It is therefore necessary to study and compare various options, from the socio-economic, technical and environmental points of view before deciding on the introduction of electricity in rural areas and identifying the energy system best suited for local energy requirements. It requires an energy demand and supply analysis as an integrated part of an allover rural development strategy in accordance with the socio-economic and environmental conditions in the area under study.

In seeking methods for integrated rural energy planning one has to understand that most of the planning methodologies were conceived in and for industrialized countries and are not or only partly applicable for rural development in remote areas.

In addition energy planning for rural areas in developing countries has to carefully match indigenous rural energy sources to the characteristics of local needs decoupled from the national energy supply system. In developing rural energy strategies the following aspects must be taken into consideration:

- Surveys have to be undertaken to identify the local needs and local resources;
- Planning must be based on the local identification of needs and local resources. This will help ensure that the introduction of energy technologies will serve the development needs of the local population directly;
- Public support and participation must be solicited. This will ensure the acceptability and success of technologies introduced.
- The number of options must be narrowed down to select only those that will optimize the development and use of energy sources;

- Appropriate technologies must be socially and environmentally acceptable.

UNIDO has therefore started to develop an integrated energy/industry planning system aiming in particular at rural energy and industry development. The system, based on a modular approach, is unique in nature, easily to be adopted by planners and analysts in developing countries and applicable for small computers. To ensure the highest possible flexibility demanded by the different status of development, the indigenous resource base and the manpower and financial situation of individual rural areas the modular system can be tailored in accordance with the required application, e.g. to be used as a whole or only on some selected modules. It is designed for easy inclusion of additional modules needed to extend the system or to satisfy specific planning requirements.

The proposed planning tools are not neutral, objective techniques valid at all times for all countries; they are not comprehensive but rather a provisional element which should be further expanded and supplemented.

The methodology, properly used, can give a first approximation for the implementation of decentralized energy systems in general and small hydropower plants in particular for rural electrification.

For an analyses of small hydropower in comparison to alternative energy supply options the following advantages are mentioned:

- Versatility of exploitation;
- Energy production independent of fuel supply;
- Contribution to the management of water resources, e.g. flood control, irrigation, supply of drinking water;
- Use of relatively simple and well developed technologies, local materials and unqualified labour;
- Low operating and maintenance costs.

Disadvantages that can be associated with small hydropower are:

- Relatively high initial capital investment costs per installed kilowatt;
- High survey cost to collect topographical, geological and hydrological information for prospective hydro sites;
- Power production affected by meteorological and seasonal conditions (load factor);
- Conflicting priorities for the use of the available water for irrigation or electricity production.

2.3. Prefeasibility and feasibility studies.

The chapter briefly summarizes the guidelines for the preparation of feasibility studies for small hydropower plants prepared by the Feasibility Studies Branch of UNIDO.

Planning for large hydropower plants is an integrated process which consists of identification, pre-feasibility studies and detailed feasibility studies. The whole process requires a thorough review after each step.

Planning for small hydropower developments cannot carry the cost of a comprehensive set-up as that of the large plants. While having components similar to large hydro plants, each small plant must be tailored to the local topographic, geologic and other conditions of the site. Lengthy analyses to achieve refinements in design do not represent the same potential cost savings for small hydropower as they do for large hydropower developments. The time input for planning of small plants must be kept to a minimum while the basis for decision-making must be established and plans which are technically and economically sound be developed.

Although feasibility studies for small hydropower plants are necessary and critical they should be kept as simple and economical as possible without sacrificing the critical information needed for decision-making purposes. To assist planners and decision makers in developing countries the following information must be included in feasibility studies for small hydropower projects:

Market and Plant Capacity:

Load demand and market;

Alternative energy sources;

Power estimates;

Plant capacity and energy production;

Power pricing policy.

Project Conceptual Plan:

Project layout;

Civil works features;

Electro-mechanical equipment;

Availability of local materials, equipment and manpower.

Plant Organization:

Manpower requirements;

Training requirements.

Implementation Scheduling:

Timing and usage of funds.

Implementation schedules.

Financial and Economic Evaluation:

Financial Evaluation:

- Project Cost Summary:
  - Investment costs;
  - Production costs.
- Project Financing:
  - Scurces and terms of financing;
  - Summary of results of financial statements.
- Financial Profitability Indicators:
  - Net present value;
  - Internal rate of return;
  - Benefit-cost ratio;
  - Break-even analysis;
  - Pay-back period;
  - Accouting rates of return.

National Economic Evaluation:

- **Appraisal of the project proposal from the national economic point of view.**

Conclusions:

- **Major advantages of the project;**
- **Major drawbacks of the project.**

Recommendations

2.4. Economy of small hydropower plants

A major aspect of feasibility studies is related to the definition of unit costs. To determine the utility of a small hydropower plant it must be compared with alternative energy sources and the cost benefit ratio must be calculated. A possible approach for decentralized electricity generation to the benefits of a small hydropower plant is determined by comparing the cost of the generated power with the cost of the same amount of power generated by a diesel-generator set.

The unit costs of small hydroelectric power can be estimated from the formula:

$$\text{cost per kWh} = \frac{k + o}{p \times l}$$

k = annualized capital cost;

o = annual operating and maintenance cost;

p = annual power generated (kWh);

l = load factor.

The following Table 3 shows the resulting kWh-cost for different discount rates, load factors and capital costs per kW installed capacity.

Table 3: Total electricity generating costs of small hydroelectric plants

Load factor	Discount rate (%)	Total cost ($/kWh)		
		$ 1.000/kW	$ 2.000/kW	$ 3.000/kW
40	5	0.04	0.07	0.11
	10	0.05	0.09	0.14
	15	0.06	0.11	0.17
30	5	0.05	0.10	0.15
	10	0.06	0.12	0.18
	15	0.08	0.15	0.23
20	5	0.07	0.15	0.22
	10	0.09	0.18	0.27
	15	0.11	0.22	0.34

For comparison a 1.000 kW diesel generator with $ 700/kW capital cost, 15 years life time, 45% load factor and $ 0,5 fuel cost per litre would have generating cost of around $ 0.14.kWh at 10% discount rate.

Table 3 shows how crucial the load factor and the capital costs are to keep the unit costs down. In general the cost per kWh largely depends on load management and the level of demand as well as the distance the power has to be transmitted. Not less important are capital costs which can be minimized with low pre-project study costs and by using locally made equipments even with compromising slightly on performance. Standardization and unpackaging of small hydropower plants towards improved local manufacturing of components with high quality and performance are important measures to overcome the high investment requirements for imported components of small hydropower plants.

2.5. Unpackaging of small hydropower projects.

Improvement of the local capabilities for the implementation and production of small hydropower SHP equipments can only be realized through a persistent and well planned programme of the needed actions for building and operating a small hydropower plant.

In this respect the time sequence for power project implementation must be given thorough consideration when discussing the unpackaging options of projects and technologies.

In the case of building a small hydropower plant with an installed capacity higher than 1,000 kW(e) the following phases must be considered:

A. Preparatory phase:

1. Hydrological studies;
2. Demand-supply analysis;
3. Project definition;
4. Feasibility study;
5. Pre-design activities:
   - preparation of specifications;
   - bid preparation and evaluation;
   - contract negotiation.
6. Project engineering;
7. Preparation of tender documents;
8. Procurement of equipment and materials.

B. Implementation phase:

9. Off-site activities including:
   - design of the equipment and setting up of quality standards;
   - production of the equipment;
   - quality control and factory tests of the equipment;
   - timely delivery.
10. On site activities, including:
   - civil works;
   - construction works, e.g. the power house, the silt basin, other ancillary facilities, etc.;
   - installation of low to medium technology and auxiliary equipment, i.e. cranes, low pressure piping, valves, gates, electrical installations, pumps, fans, etc.;
   - assembly and on site testing of the main equipment, i.e. penstock, hydraulic turbine, speed regulator, electricity generator, electrical and mechanical protection equipment, etc..

C. Exploitation phase:

11. Operation of the SHP plant and of the local grid;
12. Timely ordering and/or local production of needed spare parts;
13. Maintenance and repair.

The above list shows a broad scope for technology unpackaging during each of the project phases that may stimulate local participation, subject to the availability of indigenous engineering and consultancy capabilities.

Even the low technology parts of the list namely preparation of the project, e.g. bid preparation and evaluation, contract negotiation, civil and construction works, e.g. the power house, the silt basin, other ancillary facilities, etc., can substantially reduce foreign currency costs of the project and in addition by creating demand for local production of certain items, may serve as an entry vehicle into the production of some of the equipment.

Thus, unpackaging of the power project and the related technological transfer will have considerable effect on local industrial development dependent on the accepted type of contractual relations.

The three main types of contracts that are commonly used in power projects are:

1. The turn-key contract: A single main contractor or consortium takes overall responsibility for the design, construction and commissioning of the project. Technology transfer is very limited, unless it is explicitly mentioned in the general supply agreements.

2. The split package (lots) contract: The overall responsibility for design and construction is shared between a relatively small number of contractors who manage, design, construct and/or manufacture the bulk of the plant. One of these contractors is usually responsible for system integration and performance studies as well as for the co-ordination of the project and contracts.

3. The multiple package (lots) contract: Within the framework of its own organization or through its industrial architect, the plant owner (utility) takes the direct responsibility for the management of the design and construction work and prepares a number of contracts.

Experiences in developing countries have shown that the existence and the appropriate qualification of national experts is the most important prerequisite for splitting power projects into lots and thus for creating a market for local product and services.

Only a defined policy for the implementation of small hydropower plants will create a reliable economic market for smalll hydropower equipment, one of the main conditions for local production of small hydropower equipments and for the upgrading of the electric power equipment industry.

There might, however, exist a conflict between the short-term goal of obtaining the small hydro electric power plants rapidly and the long-term objective of increasing self-reliance. A possible balance between the two aspects can only be achieved with a long-term policy.

2.6. Different stages related to the local manufacturing of small hydropower.

It has been recognized that in both developed and developing countries the capital goods sector has evolved in essentially similar ways.

In the first stage manufacturing is limited to the metal processing sector, e.g. some companies in Ghana and Tanzania currently are specialized in manufacturing, repairing and producing spare parts for machinery. At this stage one can already enter into the production of simple small hydropower or electrical equipments sin the necessary capabilities and tools are identical or very similar to their previous metal-processing activities.

In the second stage the firms may begin to produce relatively simple machinery. In this stage the barriers to entry are still low influenced by a combination of a variety of factors, e.g. abundant and cheap labour, local and inexpensive raw materials, relatively simple designs, etc..

In the third and subsequent stages technological capabilities are progressively upgraded leading in final stages to the ability to design internationally tradeable efficient machinery.

The above general framework of the development of capital goods industry can be translated into the following groups of electrical power equipment manufactured goods and services for small hydropower plants forming subsequent plains of development:

(Plain 1): Basic goods and services

Products : Items based on indigenous materials, e.g. wooden distribution poles, some isolators, etc..

Services : Civil construction.

Main characteristics : Uses almost unprocessed local materials, is labour intensive and needs a very low capital layout.

(Plain 2): Low technology goods and services

Products : Fabricated metal products, simple electrical machinery, e.g. metal transmission towers, Banki-Mitchel and simplified Francis turbines, twisted wire, etc..

Services : In-country ability to develop plant design and detailed specification, the ability to assemble and install small-scale hydro equipment, and to design and to develop rural distribution systems.

Main characteristics : low technological level, labour intensive, low capital layout. This group already can make substantial contribution to decreasing the imported component of the electric power systems.

(Plain 3) Medium technology goods and services

Products : Broader range of Francis and Pelton water turbines, distribution equipment, switchgear, small scale motors, insulators for high voltage suspension systems, etc..

Services : Construction supervision is done by nationals. Construction of the substations and transmission systems is done by local firms.

Main characteristics: The process of technological transfer is of ever increasing importance. The capital intensity of the production processes increases, e.g. establishment of foundries and forgeries, leading also to increased requirement for specialized skills.

(Plan 4) Moderately advanced goods and services

Products : All types of water turbines, power and substation transformers, large AC motors, etc..

Services : High level design capabilities, e.g. modelling of the performance, materials testing and R + D capabilities.
Main characteristics: This group needs a developed industrial structure, skill differentiation and substantial capital/output ratios of production. Mastering of the production processes needs licensing and agreements on transfer of technology that are controlled by few multinational corporations.

(Plain 5) High technology goods
Products : Electric generator sets, measuring and control instruments, etc..
Services: Needs mature industrial structure, especially developed engineering and metallurgical industries, highly qualified labour and very high capital investment.

The local production of micro-hydro turbines (Plain 2: Low technology items) is therefore already realistic in a large number of developing countries with the exception of some least developed ones.

2.7. Multipurpose units approach.

A multipurpose approach in industry means the use of the same production equipment and manpower to manufacture several products in relatively small batches aimed at maximizing the production capacity utilization.

The integration of the multipurpose units into the capital goods sector in general and the electric power equipment production in particular widens the scope of the multipurpose approach.

Main characteristics of this approach are:

- flexibility between the product and the technological process of production;
- production process based on universal machinery designed to perform a set of basic operations, e.g. cutting, welding, machining, etc., in which labour plays a determining role;
- production of relatively small quantities of the variety of products having low to medium technological complexity;
- suitable for horizontal integration with the domestic technological infrastructure.

It is equally important for multipurpose units to be designed and operated in a way which would make it possible for developing countries to accumulate the technological knowledge needed for mastering the technology.

The following three main types of multipurpose units can be of relevance to the small hydropower equipment production, especially during the start-up stage:

1. Multipurpose machine shops;
2. Multipurpose repair and assembly shops;
3. Multipurpose mobile assembly units.

3. International co-operation

In accordance with the ever increasing interest in developing countries small hydropower constitutes an important part of the energy-related assistance programmes of many international organizations, especially those of the United Nations system.

The programmes offered by these organizations include services ranging from the assessment of river basin resources through planning, training, technology, manufacture of equipments and financing of small hydropower plants.

The following organizations provide support to the development of small hydropower in their field of specialization:

- United Nations Industrial Development Organization (UNIDO);
- United Nations Department for Technical Co-operation for Development (UN-DTCD);
- Food and Agriculture Organization (FAO);
- International Labour Organization (ILO);
- United Nations Development Programme (UNDP);
- United Nations Educational, Scientific and Cultural Organization (UNESCO);
- World Meteorological Organization (WMO).

An important part of their assistance to promote the use of small hydropower is the support of the establishment of local infrastructure in planning, studies, design, operation, maintenance, manufacture, administration, financing and technological development.

Financing is one of the most important factors to promote small hydropower schemes. The following international banking institutions are playing an important role:

- World Bank.
- African Development Bank;
- Asian Development Bank;
- Central American Bank for Economic Integration;
- Inter-American Development Bank ;
- International Finance Co-operation;

Regional and subregional co-operation involves research, studies and construction activities and may be undertaken by a group of three or more countries, under the co-ordination of a regional orgaaization or scheme. The following regional organizations are involved in small hydropower development:

- United Nations' regional organizations: ESCAP, ECLAC, ECA, ESCWA, ECE;
- Latin American Energy Organization (OLADE);
- Organization of African Unity;
- Organization of Central American States;
- Hangzhou Regional Centre for Small Hydropower (China).

Finally, many industrialized countries offer bilateral technical and economic assistance for implementation of small hydropower in developing countries.

4. UNIDO's programme on small hydropower

In accordance with its mandate and priority programme the main purpose of UNIDO's assistance in small hydropower is related to improved exploitation for hydro resources for energy supply for industrial development of isolated rural communities, the promotion of rural industries, the local manufacturing of equipments and related aspects.

In an early phase, the main scope of UNIDO's assistance had been to motivate developing countries for the application and local manufacturing of small hydropower for rural industrial developmnent by creating regional networks for co-operation in research and development and organizing workshops, training courses, seminars and study tours.

UNIDO has also supported the publication of documents related to small hydropower, including country papers, technical reports and documents of general interest such as:

- Manual for mini hydro generation Unit;
- Chinese Experience in small/mini hydropower generation;
- Mini hydropower Stations (A Manual for Decision Makers);
- Technical Manual for Design Standardization and Fabriction of Equipment and Machineries for Small Hydropower Stations.

(Details see: List of References - Attachment I)

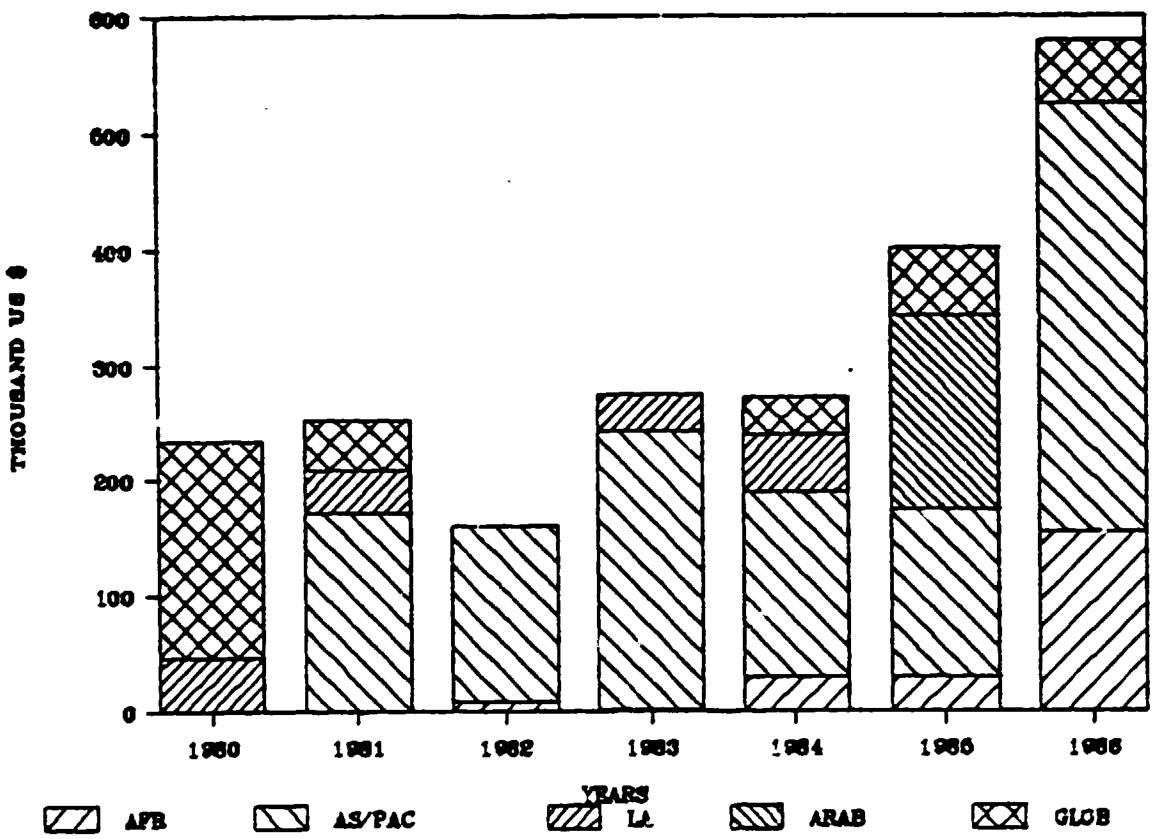
As a consequence of the growing interest in developing countres on active programmes, UNIDO's assistance is now concentrated on the implementation of small hydropower schemes in individual countries.

The development of UNIDO's technical co-operation programme on small hydropower between 1980 and 1986 is shown in Fig. 1 with a total of 23 completed or ongoing projects with total expenditures of around US$ 2,2 Mio.. The change in percentage share between the different regions demonstrates that increasing attention is paid to the least developed and the African countries. Priority areas of the programme are:

- Planning and integration of small hydropower into rural industrial development;
- Pre-feasibility and feasability studies;
- Designing of small hydropower plants, including civil engineering;
- Technological development, technology unpackaging and standardization of components and system for local manufacturing;

- Support of regional co-operation and exchange of technical information;
- Investment promotion;
- Training, organization of workshops and seminars, fellowships, study tours and on-the-job training.

Fig.1: UNIDO's Technical Co-operation programme on small hydropower 1980-1986 - total expenditures; percentage share of regions.



5. Procedure to get the assistance from UNIDO

Technical co-operation is an initiative based on the concept of tripartite partnership between a participating government, UNDP and UNIDO. UNDP is represented in most developing countries by a Resident Representative who is responsible for the co-ordination of all UNDP activities in the country. In some countries, a UNIDO representative (Senior Industrial Development Field Adviser/SIDFA) is attached to the office of the UNDP Resident Representative. The SIDFA is responsible for all UNIDO matters in that country, in particular to generate new projects and follow-up on existing ones bearing in mind the Government's priorities.

The recipient government is a full partner in the tripartite arrangement. As a rule, recipient governments designate one of their central authorities to co-ordinate government participation in UNDP/UNIDO technical co-operation programmes; this authority is usually referred to as "government co-ordinating unit".

UNIDO, as an executing agency, is the third partner in this arrangement. With UNDP providing the financial inputs under the "Country Programme", UNIDO, in co-operation with the host government, is the executing agency responsible for programming, formulating and carrying out the project activities. The executing agency, UNDP and the government undertake a tripartite evaluation of activities in particular sectors, sub-sectors or areas with a view to identifying specific problem areas which require a reformulation of the project and preparing new programmes.

The following steps are necessary to initiate a technical assistance co-operation project.

The first step is for the requesting department or ministry in the Government to contact the UNIDO Senior Industrial Development Field Adviser (SIDFA) or the UNDP Resident Representative in the country, explaining as detailed as possible the technical assistance required. The requesting government should identify the entity responsible for the project (Government Implementing Agency), the local services and facilities which will be made available and the financial resources if any which will be provided to the project (cost-sharing).

Following these preliminary steps, a draft project concept should be prepared jointly with the local SIDFA and forwarded to the UNIDO Secretariat for technical review and elaboration into a full-fledged project document which will include basic data on the:

- Project objectives;
- Background and justification;
- Project outputs;
- Project activities;
- Project inputs;
- Evaluation plan;
- Envisaged follow-up.

The Project Document will be then forwarded to the Government and UNDP for approval and signature.

After the approval the project will be implemented by UNIDO in co-operation with the Government Implementing Agency in accordance with an established Work Plan.

Conclusion

The development of electricity generation from indigenous renewable resources with the most suitable local inputs and technologies is a major strategic element for agro- and small-scale industrial development in rural areas in developing countries.

Taking into account the existing technical skills, local infrastructure and socio-economic conditions in rural areas, simple technologies should be used to convert solar, wind or hydropower into sources of electricity with maximum local input for the manufacturing, construction, operation and maintenance of the systems.

Small hydropower schemes, not yet used on a significant scale in developing countries, should receive particular attention since they could facilitate simultaneous attainment of industrial, environmental, economic and social objectives.

In this context the Chinese experience with small hydropower is interesting. By the end of 1984 about 74.000 small hydro stations with a total installed capacity of 9060 MW were in operation with a total electricity generation of 20.8 TWh. About 40% of the installed capacity is providing electricity to small decentralized grids producing one third of the total electricity consumed in remote rural areas.

The following successful experiences in small hydropower development in China might be of interest for developing countries:

- With the use of local materials and skills small hydropower development was adapted to local conditions and local manufacturing of equipments resulting in a reduction of costs and time of construction;
- Topographic and hydrological surveys. design, construction, operation and management of small hydropower plants are carried out with local resources;
- The funds required for development were raised by local governments, co-operatives and individuals;
- Multi-purpose and cascade development gave full utilization of the water resources and produced optimal techno-economic results.

The specific problems with the small hydropower development in China clearly emphasize priority areas for UNIDO's technical co-operation programme and assistance provided to developing countries.

The outstanding problem is the low utilization or load factor of the small decentralized hydropower plants. Integrated electricity demand and supply planning and industrial and infrastructure development are important prerequisites to improve the utilization of the installed capacity including seasonal electricity consumption for processing of farm products and irrigation. Another problem is the emphasis during the planning and implementation stage on low construction cost per kW rather than the cost per kWh of electricity generated. Appropriate technical-economic feasibility and cost-benefit studies are needed as a basis for the decision-making process.

Other problems are the large number of different designs and low level of automation as well as transmission and distribution systems with simple and crude equipments. Standardization of equipments in accordance with existing infrastructure and skills including guidance for quality assurance and control and unpackaging of systems are solutions considered at the present meeting. Finally poor operation, management and maintenance require a strengthening of the training and education of the local personnel as well as of institutional systems for the necessary operating rules and regulations.

In accordance with its mandate UNIDO is prepared to provide assistance to overcome the present constraints in many developing countries for a reliable and econonic use of small hydropower for rural electrification as one of the driving forces for industrial development and improved standard of living.

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