# THE UNITED NATIONS DEPARTMENT OF TECHNICAL COOPERATION FOR DEVELOPMENT AND THE ROYAL NORWEGIAN MINISTRY OF DEVELOPMENT COOPERATION



# SEMINAR ON SMALL-SCALE HYDROPOWER KLÆKKEN, NORWAY, JUNE 10 TO 18 1985

A REPORT OF THE PROCEEDINGS PREPARED BY THE UNITED NATIONS DIVISION OF NATURAL RESOURCES AND ENERGY, DEPARTMENT OF TECHNICAL COOPERATION FOR DEVELOPMENT AND THE NORWEGIAN WATER RESOURCES AND ENERGY ADMINISTRATION

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NOTE: The designations employed and the presentation of the material in this report do not imply the expression of any opninion whatsoever on the part of the secretariat of the United Nations concerning the legal status of any country, city or any of its authorities, or the delimitation of its frontiers or boundaries.

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FOREWORD

This Report presents, in abbreviated form, the proceedings of the Seminar on Small-Scale Hydropower held at Klækken, Norway in June 1985. The Seminar was arranged by the United Nations Department of Technical Cooperation for Development and Norway's Ministry of Development Co-operation and the Norwegian Water Resources and Energy Administration.

The Report has been edited by the United Nations and published by the Norwegian Water Resources and Energy Administration (NVE). It is based on written contributions from no less than 38 different individuals from almost as many countries who participated in the seminar. We are grateful to all contributors to this report and have checked the texts with them wherever possible. Any ommissions or errors are inadvertant and regretted.

NVE's work on the report has been greatly facilitated by the active cooperation of the United Nations Department of Technical Cooperation for Development.

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MAP

Itinerary of the Study Tour, 16-18 June.

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### 1.1 THE SEMINAR

Under the auspices of the United Nations, the Royal Norwegian Ministry of Development Co-operation and the Norwegian Water Resources and Energy Administration, an international seminar on <u>Small-Scale Hydropower</u> was held from 10-18 June 1985 at Klekken, near Oslo, Norway. The Seminar was attended by about 70 experts, including representatives from 25 developing countries, officials from the United Nations and the Development Banks and by Norwegian and other Scandinavian professionals.

Some 16 professional papers, covering all aspects of small-scale hydropower, including energy policy, planning methodologies, power markets, financial and economic appraisal, civil and mechanical works design, equipment manufacture and power plant operation and training were presented to the Seminar. In addition, 21 Country Papers were presented and discussed, illustrating a very wide range of experience in the small-scale hydropower field, from areas as diverse as the Andes Mountains in Peru to the Lofoten Islands in north Norway.

The Seminar consisted of five days of lectures and discussions at Klekken, followed by an intensive three-day tour of some of Norway's most interesting hydropower sites in the west and middle of the country (see map). Delegates were able to view the world's most powerful Pelton turbine in operation at Sima on this tour.

A major purpose of the Seminar was to bring together practitioners in small-scale hydropower, from many developing countries, to compare experiences. They were also able to study the experience of the United Nations and Norway in the small-scale hydropower field.

Norway has enjoyed electrification for over 100 years, and few countries have derived greater social and economic benefits from the introduction and operation of hydroelectric power, both large and small. Virtually all of Norway's electricity is now derived from hydropower. In 1985, only 3 per cent of the electricity came from small-scale hydropower units, i.e. under 10 MW installed capacity. However, at an early stage of electrification, for instance in 1922, one-third of the production capacity derived from small-scale plants under 10 MW capacity. This historic progression, from small-scale to large-scale hydroelectric power, is one of the most interesting phenomena in the history of electricity. It has brought Norway to the position of being the largest per capita consumer of hydroelectric power in the world. In 1982, the annual per capita consumption of electricity in Norway was 22,325 kWh, while in the United States it was 9,660 kWh per capita. In the Republic of Burundi, with a population about the same size as Norway's (4 million), per capita consumption was 14 kWh. Norway has therefore consciously used hydro-electric power (starting on a small-scale) to promote the country's overall development in an unparalleled way. Many representatives from developing countries found much of interest in Norway, especially as regards the effect of electrification on social and economic change.

## 1.2 THE SEMINAR PROGRAMME

The Seminar was opened by Norway's Minister for Development Co-operation, and this was followed by a series of introductory Contributions by Norwegian and United Nations officials (Chapter 3 of this report). Lectures were then given under the headings of:

Project Planning (Chapter 4): 6 lectures Decision-Making (Chapter 5): 3 lectures Project Implementation (Chapter 6): 2 lectures Operation and Maintenance (Chapter 7): 2 lectures

Country papers were also presented and discussed (Chapter 8).

A copy of the Programme is attached at Annex 1 to this Report. Annex 2 lists the Participants.

## 1.3 THIS REPORT

A total of 611 pages of written contributions were submitted to the Seminar organizers. These contributions, from over 30 different Countries, obviously vary greatly in content, presentation and degree of detail. The Seminar organizers, under the direction of Mr. Asbjorn Vinjar of the Norwegian Water Resources and Energy Administration, therefore decided to prepare this much abbreviated and edited version of the contributions received. It is hoped that this Report will be of a manageable size and more readily understood by the general reader. Those seeking greater detail on the contributions behind this Report should write to Mr. Asbjorn Vinjar, Director General, Norwegian Water Resources and Energy Administration, P. O. Box 5091, Maj., 0301 OSLO 3, Norway.

#### 2.1 GENERAL

This chapter sets out a statement which summarizes the main findings, conclusions and results of the Seminar to outline the state of the art in small-scale hydropower. This should assist policy-makers in determining the role, relevance, benefits and limitations of small hydropower planning, technology and operations in different environments.

The Seminar Rapporteur has prepared this statement, under the direction of the Seminar Director, Asbjorn Vinjar, from notes taken during the Seminar and from submissions from various participants during the Summing-Up Session.

The statement was circulated to all Seminar participants on 11 July 1985. Any comments, amendments or additions were to be transmitted to the Seminar secretariat by the beginning of September 1985. Some 11 participants communicated written comments which have been reflected in this statement.

The statement falls naturally into three main headings:

- Planning and Design;
- Financing;
- Implementation and Operation.

## 2.2 PLANNING AND DESIGN

- 2.2.1 In planning and design of SHP there is "no substitute for knowledge". At the same time the Seminar recognized that pre-feasibility studies can often be performed very quickly. In some cases pre-feasibility and feasibility studies were too elaborate. Often this duplicated one another. This, of course, is not to disqualify the importance of such studies, but rather the inadequacies in their terms of reference.
- 2.2.2 SHP projects, implemented in large numbers, can add up to large-scale programmes. "Small-scale in large-scale" is an important concept in the planning and design of small-scale hydropower.

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- 2.2.3 Standardization of designs within SHP offers great potential (e.g. standardized microturbines, governors and control panels reduce cost) but it does not diminish the need for feasibility studies.
- 2.2.4 Considerations should be given to the adoption of standardized designs, even in cases where such designs do not fit exactly the site characteristics. This may result in reduced project costs. More or less standardized designs may be available, both for the components of a scheme and for certain types of scheme as a whole.
- 2.2.5 As a corollary to the above point, equipment manufacturers should be involved in the site planning process and even in site selection for SHP. Specifications for SHP projects are often far too detailed, giving little room for flexibility.
- 2.2.6 SHP, often in remote and isolated communities, can be used as an instrument of social and economic policy to promote active economic development. Small-scale industry may often be introduced in remote areas to help justify the development of SHP projects, especially where such industry can avail itself of seasonal energy which otherwise may go to waste.
- 2.2.7 Rural electrification, often implemented through SHP schemes, is an integral part of rural development schemes.
- 2.2.8 Considerations must be given, particularly in remote areas, to possible combinations of SHP with other energy alternatives, using indigenous energy resources where possible, in order to guarantee that the minimum energy requirements of an isolated rural community are met.
- 2.2.9 For small-scale projects, planning should be concentrated on the more complex civil engineering aspects. Electromechanical components can often be standardized with the help of manufacturers. It is also noted that it is the civil works component of SHP which will be decisive in the overall cost of a project and will require the greatest amount of local participation.
- 2.2.10 Because of the time needed to carry out civil works investigations and to establish cost estimates for an SHP project, it is often desirable to approve an SHP project <u>in principle</u> before final project costs are known. If civil work costs thereafter emerge as excessive, the particular project can be reconsidered and reformulated or even abandoned by the project promoter.

- 2.2.11 There is a clearly recognized need among the developing countries to promote the exchange of information on SHP between countries. A number of useful models already exist for promoting such exchanges.
- 2.2.12 There is a clear need to rationalize methodologies for feasibility and design studies of SHP programmes and projects. This applies not only to technical feasibility studies but also to more comprehensive studies which incorporate demand analysis, financial analysis, technical analysis and sometimes national cost-benefit analysis. Such comprehensive studies will be needed if the full potential of SHP as an instrument of social and economic policy is to be achieved.
- 2.2.13 The Seminar expressed strong views on the need to pay greater attention to hydrology, for hydropower in general and small-scale hydropower in particular. It was recommended that Governments and UN agencies should pay more attention to the collection and dissemination of hydrological information. Greater concentration on improving hydrological data would do much to facilitate small-scale hydropower development in developing countries. There would appear to be a shortage of long-term records of good quality hydrological data for the small rivers on which SHP depends in most developing countries. This inhibits the planning, design and implementation of SHP although techniques are available to define design discharges.
- 2.2.14 Hydrological investigations can be expensive, but they are essential for the effective planning and design of SHP. Revenue-generating authorities, such as electricity supply undertakings, should be charged with the task of co-ordinating and processing hydrological data needed for the expansion of their operations.
- 2.3 FINANCING
- 2.3.1 In SHP, more than in most sectors, there is a clear need for alternative approaches to financing by the international financing community. Expenditure is high and revenues are low at the inception of a project, and this is the reverse of the requirements of conventional financing arrangements. There is a need for radical rethinking in financing SHP, especially with the decline of large-scale projects in many developing countries.
- 2.3.2 Although electricity supply is generally subject to normal economic and financial criteria, and should be considered as a priceable commodity, conditions for provision of electricity should be no stricter than those for supply of other basic services, like roads, water, education and health.

- 2.3.3 Many developing countries have experienced real frustration with the financing of SHP projects. Many countries found it extremely difficult to comply with all the terms laid down by international financing institutions. Such institutions must try to be more flexible and understand the limits imposed on some countries by economic constraints, particularly as such projects are regarded as a basic and essential service.
- 2.3.4 There seems to be a basic financial paradox in getting electrification going in some developing countries. By definition, a project emerging from a barter economy must be uneconomic. It seems that subsidy, in some form or other, is inevitable at the beginning of the electrification process. This experience was shared by most industrial countries when they first introduced electrification.
- 2.3.5 In assessing the viability of projects, planners should be aware of the direct contribution which electricity can make to socio-economic "take-off", more so than other components of the rural infrastructure such as water, roads, health, etc. Electrification should therefore be treated in the same way as other social and rural infrastructure elements. It was pointed out, however, that overemphasis on the technical aspects of a project had been responsible for hampering the financial and economic evaluation of projects, and thereby the funding.
- 2.3.6 It was agreed that single SHP projects developed in isolation were often not of sufficient size to attract the interest of financing institutions. It is frequently desirable to group isolated projects into an overall ("larger scale") programme of projects in order to attract favourable financial terms.
- 2.3.7 There seems to be a clear "information gap" in both directions between donors and recipients. One way of reducing this gap is to establish institutional co-operation between professionals in developed and developing countries. The professional agreement between the Norwegian and Mozambican electricity authorities was mentioned as an example of this.

#### 2.4 IMPLEMENTATION AND OPERATION

- 2.4.1 The importance of local participation in SHP was emphasized. Community-based initiatives are essential in developing "small scale in large scale" projects. Examples of such initiatives are readily available from the pioneering days of electricity in several countries such as Norway and the United States, and more recently the Philippines and China. Local participation in the electrification process can do much to mobilize local capital and labour for construction.
- 2.4.2 Organization is the key for establishing a demand for electricity. Local populations should be encouraged to demand electrification, and a key question is how to arouse and sustain interest in electrification within a subsistence economy.
- 2.4.3 The type of organisation needed to implement SHP is one which is capable of implementing many projects simultaneously. Centralized monolithic state monopoly organisations are frequently not conducive to a broad-based development effort.
- 2.4.4 Training routines during project implementation should be developed to include maintenance as well as operation of the system.
- 2.4.5 In some cases it is important to build up construction and management capacity during the implementation period of SHP by contracting consultants to supervise construction. But responsibility for overall implementation and for subsequent operation and maintenance will lie with the developing country concerned.
- 2.4.6 SHP projects can be included in overall integrated rural development projects in order to increase their chances of obtaining finance. But the difficulties of integrating several sectors into one programme should not be under-estimated; they may have to be co-ordinated at the sub-regional level.
- 2.4.7 The issue of local manufacture of SHP equipment is an important one. Local manufacturers are often precluded from bidding on internationally-financed projects because of bidding rules and excessively detailed specification requirements.
- 2.4.8 It is suggested that a specialized workshop be organized to look into the problems of local manufacture of SHP in developing countries and specially into the development of an adequate local capacity in the civil engineering sector.

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- 2.4.9 A precondition for development of a manufacturing industry is long-term support by Government of a rational SHP development programme and a policy of local purchase.
- 2.4.10 Many countries have internal markets which are too small to justify establishment of local manufacture of SHP equipment. Regional marketing arrangements may therefore be required if local manufacture is to be promoted. This also applies to standardisation of designs within and between developing countries.
- 2.4.11 Because markets for local manufacture of SHP equipment are small, it may be useful to start with maintenance and rehabilitation of existing machines. This can stimulate the utilization of used equipment and improve familiarity with SHP technology for manufacturing purposes. It was noted that basic turbine design does not become out-dated.
- 2.4.12 The Seminar considered that small-scale non-governmental organisations were often good agents for introducing and maintaining SHP projects in developing countries. Because of their form of organization, they were often able to offer greater continuity and an active presence on the site, which helped greatly in the operation and maintenance of equipment.
- 2.4.13 The Seminar would like to see the development of a pilot small-scale hydropower project (of no more than 1,000 kW) in a remote and isolated area, not yet electrified, within a developing country, so that the impact on remote rural societies can be demonstrated. Negotiations have already begun on this aspect.

#### 3.1 GENERAL

An important purpose of the Klekken Seminar was to hold a professional meeting on small-scale hydropower in a country which owes much of its present prosperity to the imaginative development of small-scale hydropower. This country, Norway, has furthermore taken an active interest in assisting other countries in harnessing their own small-scale hydropower resources through its bilateral and multilateral development assistance programmes.

For this reason, the Klekken Seminar opened with a series of addresses by Norwegian and United Nations officials and experts which sought to put small-scale hydropower into its global perspective. It became evident that not only Norway, but also several United Nations agencies were actively promoting the development of small-scale hydropower, as an effective, renewable and non-polluting source of energy, suitable for most developing countries possessing the requisite physical conditions.

This chapter summarizes the addresses presented during the opening session of the Klekken Seminar and attempts to summarize some of the discussion which followed.

#### 3.2 NORWAY

Norway's Minister for Development Co-operation, Mrs. <u>REIDUN BRUSLETTEN</u>, undertook the formal opening of the Seminar, on behalf of her Ministry. The Minister pointed out that it was most appropriate to site the Seminar at Klekken in the county of Buskerud, in central Norway, which was also the Minister's home area. She had found that the county of Buskerud, with a population of 200,000 people in a rural area produced as much electricity as a country like Indonesia, which has a population of 150 million. This showed that a simple farming people like the Norwegians, blessed with the basic physical resources of water and mountains, had been able to develop a truly enormous power potential and to harness it for the good of all people. This showed that <u>anyone</u> could do it, given the basic physical resources.

Small-scale hydro-electric power began in Norway over 100 years ago, with a few enterprising small farmers damming up streams and installing simple power plants. The emphasis then was always on

<u>small</u> projects, which could serve a farm, a little mountain village or an isolated valley industry. Because of the extremes of climate and the small population, necessity had become the Mother of Invention, and Norwegians had developed electricity because they <u>had</u> to. Now, 100 years later, Norway is probably the most highly electrified society in the world. But it all started from humble beginnings in small-scale hydropower, in conditions not dissimilar to those found in the poorest of today's developing countries. The lesson was plain, that everyone could do the same, given the same resources.

The Government of Norway assists numerous countries and provides assistance to hydropower projects in Burma, Lesotho, Mozambique, Nepal, Philippines and Tanzania. Lack of a cheap and reliable source of energy for low-income households is a major hindrance to social and economic development in these countries. For example, lack of electric light reduces the possibility for study at night. Many of the countries which Norway is assisting contain small isolated rural communities, like those in Norway, which can benefit directly from the introduction of small-scale hydropower schemes for rural development.

The Minister welcomed all those present to Norway and concluded by pointing out that the population in her area had much to be thankful to hydropower engineers for.

Mr. JAKOB STORAAS, Head of Energy and Telecommunications within the Norwegian Agency for International Development (NORAD) in the Ministry for Development Co-operation, addressed the Seminar on the Ministry's programme of assistance to developing countries with special reference to the energy field. The Ministry for Development Co-operation was founded in 1984, and, before that, Norway's development assistance was administered by the Ministry of Foreign Affairs and NORAD.

The value of Norway's development assistance programme in 1984 was about US\$ 550 million or about 1.15 per cent of Gross National Product. Norway concentrates its assistance on nine major partner countries viz. Bangladesh, Botswana, India, Kenya, Mozambique, Pakistan, Sri Lanka, Tanzania and Zambia. In the energy field Norway is making a special effort, in co-operation with Sweden, to assist the nine countries of the Southern African Development Co-ordination Conference (SADCC).

Mr. Storaas noted that the White Paper on development assistance produced by the Government in October 1984 stresses the importance of increased support to hydropower, but felt that too much time was being put into the planning and decision making phases of projects. He felt a more direct approach, such as that adopted by NORAD in Mozambique and Lesotho, was more appropriate. He also stressed that Norway views small-scale hydropower development as an essential part of an integrated rural development programme, as power is an essential element in developing other sectors of the economy. Norway's support for small-scale hydropower projects in Nepal, which were stimulating agriculture, irrigation, small industry and power development, was a very good example of this.

Mr. <u>ASBJORN VINJAR</u>, Director General in the Directorate of Energy in the Norwegian Water Resources and Energy Administration (NVE), delivered a keynote lecture during the opening session on "Norwegian <u>Energy Policy with Special Reference to Small-Scale Hydropower</u>." This was a lengthy paper, outlining the history, development, present and future role of small-scale hydropower in Norway. His lecture was illustrated by a series of diagrams.

During most years, Norway's electricity supply is based entirely on domestic waterfall energy. Norway also possesses very large resources of hydrocarbons on the Continental Shelf and also exploits solid fuels in the form of fuelwood and coal. Electricity accounts for about 70 per cent of the total demand for energy in Norway, and petroleum, coal and fuelwood make up the other 30 per cent. One third of electrical energy produced in Norway, i.e. about 30 TWh is used in the production of power-intensive commodities, like metals, alloys, petrochemicals, pulp and paper.

It has been estimated that the total economically feasible hydropower production potential of Norway is about 170 TWh, of which about 60 per cent or 100 TWh is currently exploited. Because of variable run-off conditions, huge reservoirs are needed to store water from spring snow-melting.

There has been growing concern about the environmental impact of continued hydropower development in Norway, and some 12 TWh of potential production capacity has already been excluded by Parliament from exploitation on environmental grounds.

Mr. Vinjar then went on to summarize the history of Norwegian electrification. Initially, the system was based in the 1880's on very small-scale hydropower units. Farmers were already well used to harnessing the mechanical energy of waterfalls through the use of waterwheels. Small-scale systems were developed on an isolated basis in a town, village or farm and then interconnected. Until 1957 there were still 27 isolated grid systems in the country, and these were not easy to link, because of distance, low population density and physical conditions. However, today the country is served by only two separate systems, to the north and south of the Arctic Circle, and both are connected to the Swedish grid. With the linking of systems, bigger power generation units could be introduced, and between 1940 and 1980 demand for large units with annual producibility of 50 to 500 GWh rose rapidly. During this period many older small-scale schemes went out of commission.

Since 1980 there has again been renewed interest in the development of small-scale hydropower projects in Norway i.e. of under 10 MW capacity. There are several reasons for this. In the first place, the general public has shown a much greater awareness in recent years of the environmental impact of large-scale hydropower schemes. Secondly, there are fewer large-scale projects now available as over 60 per cent of the potential has already been developed. Thirdly, standardization and simplified design within the small-scale hydropower sector have helped in recent years obtain economies of scale similar to those achieved within large-scale hydropower.

The Norwegian authorities define any project of 10 MW or less as "small-scale", because plants and components can be standardized up to about 10 MW capacity. Thereafter, plants of more than 10 MW have to be engineered more precisely to the site conditions. In Norway, potential waterfall sites for small-scale hydropower plants are traditionally private property which can be bought and sold. In order to encourage greater development of small-scale hydropower, the Norwegian Water Resources and Energy Administration has registered a large number of potential small-scale hydropower sites. In addition, the Board supports up to 75 per cent of the cost of any prefeasibility planning required for development. However, because of the existence of an integrated power supply system, fed by all production units in the country, small-scale hydropower technology in Norway has to be extremely efficient in order to be able to compete with other energy projects which feed the national grid.

Unlike most industrialized countries, Norway is rich in low-cost energy resources, and is able to export a large proportion of its surplus petroleum, gas and coal. There is still sufficient hydropower potential available to raise the proportion of ordinary stationary energy consumption provided by electricity from today's 70 per cent to 85-90 per cent by the turn of the century. NVE has defined a total of 170 potential projects for its development programme for the next 15-20 years. This programme is somewhat similar to that developed in the early part of the century in Norway, i.e. it contains a large number of relatively small projects spread widely throughout the country. However, these will feed into a national power grid rather than constitute isolated power centres in themselves.

In conclusion, Mr. Vinjar mentioned the development in Norway of "wave power", which is regarded in Norway as a form of "hydropower". Present pilot projects near Bergen demonstrate that wave power may well be able to compete favourably with diesel power and small-scale coal-fired plants.

Norway is therefore currently moving away from the development of large-scale hydropower resources towards a new era of small-scale hydropower. The situation is somewhat analogous to what is happening in many developing countries, i.e. emphasis is placed on the electrification of remote regions and regions with scattered population. Collaboration between Norway and developing countries with hydropower sited on ocean coast lines is thus of particular value and interest.

#### 3.3 THE WORLD

Some four speakers from the United Nations system described the efforts being made by the various UN bodies to promote and extend the use of small-scale hydropower throughout the world.

Mr. NICKY BEREDJICK, Director of the Natural Resources and Energy Division (NRED) in the United Nations Department of Technical Co-operation for Development (UNDTCD), New York, addressed the Seminar. The United Nations Department of Technical Co-operation for Development is charged specifically with the formulation and execution of technical assistance projects in energy (including small-scale hydropower) in developing countries. The Department provides advisory services to developing countries in energy development. The Natural Resources and Energy Division has instituted a number of programmes to support small-scale hydropower development through technology transfer and strenghthening the capacity of developing country personnel for undertaking the planning and implementation of promising projects. An important part of this work has been a small-scale hydropower survey, to identify promising projects warranting implementation within developing countries. A total of 48 countries are to be visited, and already 33 have been studied.

In addition, UNDTCD is supporting specific feasibility studies on small-scale hydropower projects in several countries e.g. Bolivia, Ethiopia and Thailand. Small expert teams drawn from international sources were formed to co-operate with local counterpart personnel in the detailed study and design of previously identified projects. A number of these schemes are now under construction and a similar cycle of feasibility studies is to be carried out in other countries.

UNDTCD also supports training programmes for small-scale hydropower. In one country, a training school was set up and 35 local engineers and technicians are being trained in small-scale hydropower development. In another country, UNDTCD has arranged for "hands-on" training. The Department is also arranging training in Canada for a number of engineers from developing countries in modern approaches to small-scale hydropower. Assistance in the operation and maintenance of small-scale hydropower facilities is given to the utilities in some countries and training courses and workshops are being provided for this purpose.

The Seminar was then addressed by Mr. <u>BRUCE HARLAND</u>, Deputy Assistant Administrator and Director, Energy Office, United Nations Development Programme (UNDP) of New York.

Mr. Harland pointed out that, despite the recent lowering of oil prices resulting from a surplus in the production of crude oil, oil-importing developing countries had gained few benefits because of the continuing strength of the U.S. dollar, the decline in commodity prices and the recent recession in western developed countries. Developing countries do not have the opportunities which developed countries possess, of rapidly readjusting their economies to suit changing circumstances. The developing countries must find alternative energy sources and small-scale hydropower seems to have some very interesting potentials. However, Mr. Harland considered it misleading to use conventional cost-benefit analysis and similar criteria in evaluating small-scale hydropower plants --- as if they were, in fact large-scale projects. Planners should analyse the future benefits of the project to the local community in terms of alternative economic growth. In addition, simpler, less costly structures should be considered in order to make greater use of human, rather than capital resources. For example simple diversion weirs with a surface flume could be used, rather than costly tunnelling. Plastic pipe could be used for penstock. In the design of turbines, maximum allowance must be made for local manufacture. The Chinese approach to local manufacture might be emulated and the Seminar would benefit from the presence of the Director for the Hangzhou Centre on Small Hydropower.

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Mr. WILLIAM TANAKA, Head of the Development and Transfer of Technology Branch in the United Nations Industrial Development Organization in Vienna, then addressed the Seminar.

Norway has been a major supporter of UNIDO's programme of activities in energy and technology. The energy crisis caused by the sudden increase in the cost of petroleum products in the mid-1970s stimulated attention to the need for development and application of new and renewable sources of energy. UNIDO has participated actively in research and development programmes on such sources but despite the optimistic views expressed, little global progress has been observed in using such alternative resources on a sustained and sound commercial basis.

Small-scale hydropower, however, has re-emerged and been "rediscovered" as one of the most realistic and practical energy sources. It is a comparatively simple technology, with a low level of initial investment costs. It can serve remote and isolated areas and has a limited environmental impact. It is relatively simple to operate and maintain and possesses the potential of promoting rural development and rural industrialization with the direct involvement of the local population.

UNIDO has been actively involved in the promotion of small-scale hydropower technology since 1976 and together with NORAD supported the Training Workshop on Small Hydropower in Kathmandu in Nepal. UNIDO now supports the building up and strengthening of the capacity of developing countries in small-scale hydropower and has supported the establishment of the Regional Network for Small Hydropower at Hangzhou in China. A range of UNIDO projects is presently in the pipeline for implementation during 1985 and 1986, with substantive financial commitments from UNDP. Most of those UNIDO activities in small-scale hydropower are based on technical co-operation among developing countries (TCDC). UNIDO has also been active in promoting regional co-operation in Latin America through OLADE, in the Caribbean and in Asia and Africa.

UNIDO viewed small-scale hydropower as an important energy resource, especially for industrial development in remote areas. The resource base was there in practically all developing countries. What was needed was a major programme for its implementation, and this Seminar could help to develop such a programme.

The final contribution from the United Nations came from Mr. KURT GOLDSMITH, Senior Technical Adviser, Energy Resources Branch in the United Nations Department of Technical Co-operation for Development (UNDTCD). Mr. Goldsmith was one of the major forces behind the holding of this Seminar and it was unfortunate that, because of illness, he was unable to attend. His contribution was read for him. His paper was entitled: "The Role of Small-Scale Hydropower in Energy Planning and Supply, Globally Seen".

As electricity came into use about 100 years ago, small generators were coupled to the water wheels, in place of the mills, looms or pumps used hitherto, to supply electrical energy to the local population. This was the beginning of hydropower as we know it. Neither the principles nor the utilization pattern of this resource have changed in any fundamental way since that time, although technology has made great progress in all fields of engineering. The concepts of small-scale hydropower, which are now so much in focus, are thus by no means new and were the basis of the electricity supply of highly industrialized countries, like Norway. The experience of industrialized countries in the small-scale hydropower field is therefore still appropriate to today's developing countries.

At first, electricity was supplied where it could be produced, but large-scale industrial demand arose increasingly in places where electricity could not be produced locally, and electricity could sometimes be produced conveniently at locations where little or no demand existed. There was therefore great pressure to develop large-scale generation facilities, and to develop concurrently interconnecting electricity networks.

Electricity supply in general thus became independent of local, and even national, availability of primary energy for its production. In major industrialized countries, small-scale hydropower therefore became a less and less attractive option. However, it appears from what Asbjorn Vinjar said in his paper that the pendulum is swinging back towards small-scale hydropower in Norway.

The scale effect, i.e. the growing size of generating units and power plants, and the greater centralization of sources of supply arising from it, tended to overshadow the decentralized supply pattern still maintained in many places but no longer receiving much attention from the energy planners. In developing countries, there have always been strong pressures towards centralization and the development of large-scale schemes. The scarcity of local capital is an important factor here, as there is a tendency for external assistance to be applied for centralized, rather than decentralized, development. These factors therefore militated against the development of small-scale hydropower in developing countries. An emphasis on economic viability, rather than on the socio-economic needs of an area, also accentuated this situation. Small-scale schemes, however, continued to be planned and built, but only where they were clearly economically viable or could be supported by policies of cross-subsidization. Diesel plants became a very attractive alternative source of electrical energy in remote local communities. They were easy to install, with very brief lead times, easy to operate and maintain and offered the necessary operational flexibility for effective local power development. Lack of co-ordinated energy planning, financial stringency and, initially, low oil prices, ultimately led to a situation in which even in areas with adequate local hydropower resources, the electricity supply became based primarily on diesel power. However, the rapid increase in fuel prices over the past decade has exposed the disadvantage of consuming fuel oil of an inherently high price, often accentuated by high delivery costs to remote areas, in order to supply customers of inadequate purchasing power. Rural development is becoming inhibited, and the division between urban and rural life, and the social stress this produces, is becoming increasingly apparent.

Within a national planning context, however, it is often difficult to make out a clear case for the development of small-scale hydropower in remote rural areas. There may be a continued need to subsidize projects, and in some cases local consumers may never be able to meet the full economic cost of their supply from a small scheme. It must, however, be recognized that the benefits from any scheme do not necessarily accrue to the local customers alone, and there may well be also important indirect benefits for the national economy as a whole, such as:

- a reduced drain on foreign currency earnings, because of import substitution (hydropower for fossil fuel power);
- less deforestation, because of the replacement of firewood by electricity, produced from indigenous sources;
- less population drift to urban areas, because of improved living conditions for the rural population.

A number of development agencies have, therefore, offered grant aid for small-scale hydropower schemes, on the premise that socio-economic factors can well outweigh the purely commercial benefit/cost considerations which are generally applied in assessing such projects.

Mr. Goldsmith then took up the issue of the financing of small-scale hydropower projects within the overall national resource

allocation. Probably more than half the cost of small-scale hydropower schemes will have to be found by the country in question. This means that a major contribution will have to be made by central national sources for local development. Local sources are not likely to be able to make a substantial contribution, either in finance or in kind. Local schemes will therefore, inevitably, enter into national planning considerations. Resource allocation for small-scale hydropower projects at a national level can involve a relatively complex series of considerations, where different economic sectors become interrelated. The extent of national involvement in promoting small-scale hydropower can then be significant. Both foreign assistance and national support may need to be mobilized to promote the scheme at the local level. It is thus very important that national planning agencies are adequately acquainted with local development proposals for small-scale hydropower.

Because of scale effects, exploitable resources for small-scale hydropower and available power markets must coincide, and this can limit the role of small-scale hydropower in national energy planning. Many countries have carried out, or are carrying out, small-scale hydropower resource surveys on a national scale, but it is important that the physical existence of resources is related to the location of power markets. Thus, a second round of specific site-orientated investigations is frequently required in order to determine the general feasibility of physically suitable sites.

In hydropower projects, which have an inherently high cost, the economies-of-scale effect is particularly important. Small-scale hydropower is expensive, and its economic feasibility depends, in most cases, on minimizing investment costs and also pre-investment activities. This means eliminating repetitive investigations and generally reducing the lead time for the development process. Nevertheless, there will be an inescapable minimum of pre-investment effort, but preparatory work and design for construction must be restricted to the shortest period possible.

Modified design and installation of more modern equipment in older existing small-scale hydropower plant is another way of developing small-scale resources. Retrofitting is quite common in industrialized countries where many older small-scale plants have become outdated and where investment for redesign and new equipment can be fully justified. Multi-purpose schemes, incorporating small-scale hydropower, are also worthy of consideration. Where water is already abstracted for purposes other than power production, for irrigation or water supply for example, a power-producing component can often be introduced at relatively low incremental cost. Any resource assessment of small-scale hydropower should examine the means available for supporting the development process. It is essential to identify the nature and timing of both external and internal assistance requirements for the process and to make sure it is available to support local and national participation.

In conclusion, Mr. Goldsmith suggested that the criteria used for the planning process for small-scale hydropower must be in harmony with national energy strategies and with social and economic targets for the national economy as a whole. Small-scale hydropower occupies a special position, because of its primary local impact and its marginal effect upon the national economy. However, one must take into account the aggregate effect of many small-scale projects, if these can be implemented under one programme.

An inescapable factor in small-scale hydropower, nonetheless, is decentralization. To what extent decentralization of energy development can be introduced depends on the administrative structure and policies of the country in question.

There is a clear danger that small-scale hydropower schemes for development in rural and remote areas are not accorded sufficient weight, because of their marginal impact on the national energy supply. It is therefore necessary, at policy-making level, to ensure that projects of undoubted merit are not excluded from the overall development process simply because of their small scale.

#### 4.1 METHODOLOGIES FOR PLANNING AND FEASIBILITY ASSESSMENT

The introductory lecture on Project Planning was given by Mr. WERNER BEHRENS, Head of the Feasibility Studies Section in the United Nations Industrial Development Organization (UNIDO). Mr. Behrens also distributed a technical paper entitled "Guidelines for the Preparation of Feasibility Studies for Mini-Hydropower Generation Plants" to support his lecture.

UNIDO has long been concerned to promote standard procedures for project planning and project evaluation. The organization's "Guidelines on Project Evaluation" has now been translated into 20 languages and is regarded as standard work in project evaluation.

In the small hydropower field UNIDO is engaged in four different ways, Firstly, it establishes and carries out prefeasibility studies and is currently working on such projects in Guinea, Ethiopia, Zambia, Kenya and Sri Lanka in identifying potential projects. Secondly, UNIDO runs about 10 seminars a year (often on a regional basis) on how to prepare technical projects for financing. Thirdly, the organization encourages investment promotion, in particular the manufacture of appropriate industrial products for small hydropower schemes. Finally, the organization is preparing conceptual manuals in order to standardize project appraisal and preparation. The "Guidelines for the Preparation of Feasibility Studies for Mini-Hydropower Generation Plants" distributed by Mr. Behrens, is a draft prepared for UNIDO on the basis of experience from Norway and the Philippines.

Cost is a critical element in small hydropower planning, as small plants cannot bear the large planning costs which large hydropower schemes are able to absorb. Therefore, there is a clear need to reduce the investment made in planning and feasibility assessment to a minimum. One way of achieving this is to standardize the way small hydropower projects are prepared. This can be done by developing the type of guidelines and project preparation manuals issued by UNIDO.

The speaker then presented the main elements of a feasibility study report for a small hydropower project, as described in the draft Guidelines. The main elements which must be included in all feasibility studies are as follows:

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4.

- Executive Summary
- Project Background and History
- Market and Plant Capacity
- Location and Site
- Project Engineering
- Plant Organization and Overhead Costs
- Manpower
- Implementation Scheduling
- Financial and Economic Evaluation.

The study cycle for a small hydropower project consists of three parts, i.e. an identification study, a prefeasibility study and a feasibility study. The Project Cycle itself consists of three phases as follows:

- Pre-Investment Phase
- Investment Phase
- Operational Phase.

In concluding the speaker emphasized the interdisciplinary nature of the planning process within the small-scale hydropower sector. The planning process was by no means only technical. UNIDO had made important efforts to improve financial and economic planning by developing appropriate analysis models for use with micro-computers.

### 4.2 SMALL HYDROPOWER (SHP) DEVELOPMENT - THE PROJECT PLANNING CYCLE

JAN LINDEMARK of NORPLAN A/S, Consulting Engineers of Oslo, Norway addressed the Seminar on the Project Planning Cycle as it applies to small hydropower development.

The planning process for large hydropower schemes has become increasingly complex in recent years. It has evolved into a number of distinct steps, where delays at any one point can have a delaying effect on the whole process. Reporting and specifications have developed so that the process has become complex and unwieldy. Figure 4.1 illustrates the planning process for large hydropower schemes.

Since the major oil crisis of 1973, there has been a growing realization that SHP projects are well suited for energy supply in remote areas. However, a direct scaling-down of large hydropower technology has not proved to be satisfactory. A new planning, design and technological process has evolved specifically for small hydropower schemes (see Figure 4.2). Of particular importance in the planning cycle for SHP is the environmental aspect. This aspect is carefully considered in <u>developed</u> countries. The same standards should be applied to projects in <u>developing</u> countries. It is difficult to generalize on the costs of planning for SHP. However, planning costs usually increase in inverse proportion to the size of the scheme. In other words, the smaller the scheme, the larger (per unit size installed) is the planning cost. This is illustrated on

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Figure 4.1 THE PLANNING PROCESS FOR LARGE HYDRO



Figure 4.2 THE PLANNING PROCESS FOR SMALL HYDRO

Figure 4.3. However, it should be observed that unit costs may fall again for micro-hydropower schemes (i.e. under 100 kW) where very simple designs and equipment may be adopted.



SMALL HYDRO (10 MW)

LARGE HYDRO

MINI (1 MW)

Figure 4.3 BREAKDOWN OF COST COMPONENTS FOR DIFFERENT SIZE HYDRO

SHP planning required all the skills required for the large hydropower planning process. However, in order to limit unit costs, all-round engineers rather than specialists are required. The SHP planning team should ideally consist of 2-3 all-rounders with skills in all aspects of power technology. The team should also be familiar with economic analysis and project appraisal techniques.

In the planning process, it is preferable if much of the data collection and assembly is set in train before the project planning team start work. Such data include hydrology, topographical, geological, population and electricity demand information for the area in question.

For identifying potential SHP projects, studies should be made of large regions, ideally the whole country. Standard methods of evaluating projects with consistent cost data should be developed so as to provide an identical basis for classifying projects into cost categories.

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MICRO (100 kW)

Sites with a minimum energy output of at least 1 GWh should be identified from topographical maps and unit costs curves for different project components derived. The most likely sites should be ranked before visiting the sites themselves, so as to give an order of priority. At this stage, work should consist of techno-economic reports on salient project features, such as catchment area, average flow, reservoir volume, dam volume, head, length of penstock, type of turbine, overall project cost etc. No socio-economic studies should be undertaken at this stage.

In preparing feasibility studies, final design and tender documents, it is important to engage potential financing institutions at the earliest possible stage. A commitment in principle ought to be obtained for a SHP development <u>programme</u> rather than individual projects, so that the planning team can study 3-5 different projects and select the best. In this way financing institutions should be able to accept relatively simple feasibility studies with a minimum of field investigations.

Socio-economic planning is important for SHP projects at remote sites and demand, tariff and training programme studies are also important in that context. Technical planning should be simple and projects may often be designed to suit standardized electromechanical equipment and local manufacturing capacity. This simplifies the design process and the reporting procedures considerably.

In the SHP field, management contracts with a large training component are frequently preferable to conventional international tendering procedures. This allows greater local participation and reduces foreign currency requirements. It is essential to engage local operating and maintenance staff in the planning and construction process of the SHP facility. The advantages of this are self-evident.

Case studies on SHP projects were presented: Strielv in northern Norway and Mantsonyane and Semonkong in Lesotho, southern Africa.

The Strielv Project has an annual production of 6.9 GWh from a head of 318 m. Total construction cost has amounted to US\$2.2 million. The feasibility study was carried out in 1982 and the entire project has been planned, designed and supervised by a three-man technical team. Construction was completed in September 1984.

In 1983 the Norwegian Agency for International Development (NORAD) agreed to finance studies of the potential for small hydropower projects in the Kingdom of Lesotho. Some eight potential sites in five villages were reviewed and 3 projects were deemed worthy of a full feasibility study. Feasibility studies including site investigations, hydrological studies, layout design, costing and economic analysis were carried out and comparisons were made with possible alternative sources of supply i.e. diesel generators and extension of the grid. Two projects were recommended for implementation. NORAD has now agreed to finance the construction of both the recommended projects. The Lesotho projects have been assisted by the involvement of the financing institution (NORAD) from the earliest stages. Secondly, the study has been definitive, covering the whole country and selecting the best projects. Thirdly, at least 50 per cent of the expatriate engagement in the projects (Norwegian) has been directed towards training local staff rather than construction and project administration alone.

#### 4.3 SITE IDENTIFICATION AND DATA COLLECTION FOR SHP

Dr. TOR AAMODT of Interconsult A/S, Consulting Engineers of Bergen, Norway delivered a paper on the identification of sites and data collection within the planning process for small-scale hydropower.

A major element of the planning process for SHP is the identification and selection of the SHP site itself. Numerous aspects have to be considered in site identification and selection. In the first instance, the actual water resource available has to be considered and studies of water availability, floods, sediment characteristics, hydraulic design requirements, forecasting for operating conditions and water quality will be needed. Furthermore, a considerable amount of data on topography and geology is needed. SHP planners also have had to take much greater cognizance in recent years of environmental factors e.g. water conditions and effect on landscape, environment and public health.

The speaker went into detail on particular aspects of data collection for site identification. These were topography and geology, hydrology, sedimentation and environment.

#### Topography and Geology

Topographical conditions are critical for site selection. Head and flow determine the size of the water resources in hydropower terms. In some cases flow can be increased through river regulation and seasonal storage, but head is more or less invariable. The available head must therefore be determined at the earliest opportunity through the use of existing topographical maps, if any. River profiles have to be determined by field measurement. Reservoir areas for SHP should be mapped at 1:10,000 scale with 2-metre contour intervals, whilst dam sites require mapping at 1:1,000 scale with 0.5 metre contour interval.

Geological investigations are needed to give sufficient data for reliable design. Sub-surface investigations in the form of sample drilling, boring, core drilling, exploration shafts and tunnels will be necessary to predict construction difficulties and possibilities of leakage.

#### Hydrology

It is imperative to have adequate hydrological data for SHP planning. At the same time such data are often inadequate or non-existent. Various indirect methods of establishing run-off data have been developed. These are predicated on the assumption that the past history of water occurrence will be repeated in the future. The quality of the historical database is therefore critical in determining an accurate set of hydrological data for future SHP planning. Simulation of hydrologic systems is a frequently used method of generating discharge data for planning purposes. Four methods are usually available. These are: direct transfer method; a hydrologic model based on transferred parameters; and a hydrologic model combined with direct measurements.

The direct measurement method is what it implies: direct measurement of hydrological data. This gives good reliability if undertaken over a longer period of time, but is generally too time-consuming for SHP planning purposes. The direct transfer method is based on the transfer of observations from a nearby catchment with similar climatic conditions. Observations in one catchment are scaled to conditions in the other catchment, and this gives the duration curve which can be used for dimensioning. This is a quick method, but much less accurate than using direct measurements. Hydrologic processes may also be simulated on the computer. Meteorological data are required as input for calculating river discharge data. This is done by using data from a nearby catchment area as a calibrated computer model on the assumption that data can be transferred from one catchment area to another. A time series of water discharges can be derived in this way, and this method of deriving a water discharge duration curve has the advantage of avoiding time-consuming observations and has a higher reliability than other methods. See also Figure 4.4 below.



Figure 4.4 ELEMENTS OF A HYDROLOGIC COMPUTER MODEL

Perhaps the best method of obtaining adequate dimensioning data is to combine direct measurements with a hydrological computer model representing the river system. The method is illustrated in Figure 4.5 below. It requires some time, but produces duration curves of good reliability.

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Figure 4.5 HYDROLOGIC COMPUTER MODEL AND DIRECT MEASUREMENTS

Apart from river discharge data, it is also important to record other hydrometeorological data, such as precipitation, temperature, wind, humidity, short-wave radiation, etc. These are of particular interest for utilizing computer models. Automatic self-recording hydrometeorological stations are of value in monitoring flood conditions, to ensure optimum operation of the SHP plant.

#### Sediment Problems

Sedimentation can cause reservoir siltation and abrasion of structures in the waterways (e.g. turbine blades). Satisfactory data on sediment conditions are therefore needed, and standard sampling methods and equipment should be employed to obtain representative data on suspended and bed load sediments. Sampling during the flood stage is especially important.

The economic and physical life of a reservoir is shortened by sedimentation. Space must be reserved for anticipated sedimentation. Much sedimentation will occur at reservoir inlets, and this can lead to the growth of phreatophytes, which may lead to a serious decline in water guality. Control of phreatophytes and removal of sediments may be justified in such cases. In long-range planning, sediment inflow can be reduced by upstream erosion control, detention structures and desilting works. Reservoir slides can also create minor sedimentation problems. However, abrasion of waterway structures is more critical. Diversion and desilting works may be necessary and sand traps and sand excluders may be needed to protect the turbines.

The worst types of abrasion caused by high speed and high directional deviation can cause both corrosion and cavitation. The amount of abrasion depends on sediment type and concentration and cavitation on the water flow over the turbine blades. Both have to be guarded against.

#### Environmental Aspects

The principal environmental impacts of SHP projects are on health, water conditions, flora and fauna, stream morphology and land use. Naturally, these are not as severe as for large hydropower schemes, but should by no means be neglected. The regulation of a reservoir can create stagnant waters favourable for the production of various habitats for disease bearing organisms like malarial mosquitoes, schistosomiasis snails etc. This must be borne in mind in the operation of reservoirs. Water conditions can be affected by unfavourable stratification of the reservoir. Lack of dissolved oxygen may lead to the growth of a variety of unwanted organisms. SHP projects can also have a deleterious effect upon flora and fauna by encouraging growth of undesirable species e.g. water hyacinths, or by interrupting natural routes for fish. The creation of a reservoir can have adverse effects on stream morphology downstream. Lack of sediment in the water can lead to degradation of the river Development of a SHP scheme can also have negative effects bed. upon land use. The creation of a reservoir may lower the groundwater level. The beneficial effect of silt deposit downstream may also be lost by building a reservoir (cf. the river Nile after the Aswan Dam) .

## Concluding Remarks

The selection of a SHP site involves numerous aspects, which can range from physical elements which can be quantified financially or economically to environmental impacts which are less easy to quantify. No "golden rule" can be given for the optimum selection of sites, and this will always depend ultimately on local conditions.

#### 4.4 IDENTIFYING MARKETS FOR SMALL HYDROPOWER

Dr. <u>DAVID ZOELLNER</u> of the International Programs Division in the United States National Rural Electric Cooperative Association addressed the Seminar on the markets for SHP. Dr. Zoellner described the different types of market which existed, the major requirements for feasible projects, load forecasting and opportunities for the private sector within SHP development. Since 1980, the National Rural Electric Cooperative Association (NRECA) of the United States has assisted over 20 countries in assessing and installing small hydropower programmes. This has been done through NRECA's Decentralized Hydropower activity. NRECA has not consciously promoted small hydropower per se, and where a market is identified, NRECA has always sought the least cost alternative whether it be installation of diesel generators, extension of a grid or establishment of SHP. It is virtually impossible to plan for a national programme based on small-scale hydropower because its cost-effectiveness and potential are so site-specific. However, conventional approaches to supplying power to remote areas, primarily with diesel, are costly and difficult to operate, so that developing countries have shown considerable interest in the SHP potential, especially for remote or inaccessible areas.

#### Types of Markets

The author distinguished between SHP in grid systems and in isolated systems. In most developing countries SHP can curtail future increases in oil imports, provide an alternative to larger power plants and provide daily peaking power. SHP is particularly effective in developing countries as an alternative or to supplement larger power plants within a national grid system. This is so because SHP systems are generally cheaper and quicker to implement. There is therefore a clear market for SHP additions to grid systems, especially where finance is limited and where there is a need to reduce dependency on oil. The primary market for isolated SHP schemes in developing countries is in regions which are ready to expand their rural electrification. However, NRECA see rural electrification as only one step in the development process. SHP in isolated areas may not always be appropriate in every developing country, and its introduction will depend on the level of development the country has already reached. In the development of SHP there is a great need for wise load promotion and management. Where load factors are low, productive power use programmes are employed to promote consumption, whilst in systems where capacity limits have been reached, load management techniques are needed to "shave" peak loads.

#### Required Market Conditions

It is difficult to generalize on the required market conditions for feasible SHP schemes, because feasibility is very much country- and site-specific. Howvever, certain factors within which SHP is feasible can be identified. In terms of financial viability, a project must be able to obtain credit, especially in foreign exchange which is required for about 50 per cent of the capital cost of SHP programmes. Feasibility is also affected by the prevailing discount rates. Experience shows that the crossover discount rate between SHP and diesel generally falls between 12 per cent and 16 per cent. Alternative energy cost will also have an effect on project feasibility for SHP, and the main competitors are likely to be diesel-kerosene plants and extensions of the grid. Institutional conditions can have an important bearing on feasibility. SHP projects and programmes cannot support expensive pre-investment studies, design work, construction and operational management and maintenance. SHP needs to receive active support from the Government to improve its overall feasibility.

#### Load Forecasting

Different approaches to load forecasting are required for areas which have had electric power previously and for areas which have not. NRECA has developed a methodology for making power requirement forecasts. In the United States these forecasts have to be drawn up by the agency borrowing funds to establish SHP. In rural areas of developing countries these techniques often indicate initial and future power consumption rates that are too optimistic. Techniques which involve the projection of historical data must therefore be used with considerable care in such circumstances. In non-electrified areas forecasting energy and demand of isolated power markets requires estimating existing end-uses which can be electrified and new end-uses. Household surveys are usually used to estimate potential demand, but these are often unreliable and produce over-optimistic results. Demand forecast must be related to the socio-economic status of the local community and willingness and/or ability to pay.

The author presented a case history of a market assessment carried out for a 300 kW project in Zaire. The steps were as follows:

- Determine service area
- Collect historical use data
- Interview present users
- Survey non-users
- Obtain letters of intent
- Determine system demand and energy requirements.

It was found that it was desirable to overestimate the demand available and to serve numerous uneconomic loads. This simply damages the overall viability of the SHP scheme. In general, forecasts were perhaps too optimistic for a number of complex reasons, largely because of the uncertainties connected with household interviewing.

#### Opportunities for the Private Sector

A case was made for a decentralized community-based development of small hydropower. When SHP projects are developed at local level, an appropriate local implementing agency is needed. In the United States cooperatives and municipal authorities are well organized to serve this purpose. Such schemes are successful in developing countries where community-owned infrastructure systems are well understood. The rural electric cooperatives in the Philippines were a good example of this. In Nepal, private sector development of small hydropower schemes has been successful. Small-scale private producers can be supported by Government purchasing surplus power. In the United States the arrangement whereby public utilities purchase power offered by private producers at avoided cost has opened up new markets for small hydropower. This has allowed small hydropower to feed cost-effective energy into the larger grid systems.

In order to encourage private-sector SHP development, a number of preconditions must be met. Government must provide strong support and capital must be available for construction. Government must give small private developers debt-service guarantees. Adequate training programmes must be made available and local involvement and interest are crucial to the success of privately-sponsored SHP development.

## Recommendations

The author made a number of recommendations. In the first instance he cautioned against over-optimistic forecasts based on experience from developed countries. Secondly, demand should be stimulated by including productive uses and by offering comprehensive financing. Finally, active government support and the involvement of local people is crucial to the success of SHP programmes in developing countries.

## 4.5 METHODOLOGIES FOR ESTABLISHING DEVELOPMENT CRITERIA AND COSTS

This paper was presented by Dr. <u>DAGFINN LYSNE</u> of Norconsult A/S, Consulting Engineers of Oslo, Norway. His paper was divided into an assessment of the development criteria for SHP, the characteristic features of SHP planning, development costs and an assessment of project viability.

The paper tries to systematize relevant experience within the planning cycle for small-scale hydropower projects in developing countries although this experience is still rather limited.

#### Development Criteria

Because electricity production is often a national function whereas small hydropower is essentially a local or regional matter, there can often be conflicts between local and national authorities. The major objectives of SHP programmes are threefold, i.e. to develop the remaining hydropower resources in a river, to supply power into an existing grid or to provide power for an isolated district or region. The latter two objectives are more important for developing countries, but methodology is less developed for these.

SHP projects to supply isolated districts have special characteristics. First, where the potential is large in relation to the demand, the least costly solution for electricity supply should

be sought. Secondly, storage reservoirs for dry season and peak period operation are extremely costly and often make SHP projects non-feasible. SHP projects can sometimes be combined with thermal generation facilities to eliminate the need for storage. Thirdly, run-of-the-river schemes are often less costly than a dam and storage project despite longer transmission line runs. Such schemes can often use diversion weirs instead of dams, and eliminate storage, in order to simplify the civil design and reduce costs. Finally, where hydropower resources are limited, there is greater need for development plans. Multipurpose aspects become more important although these can also complicate the project. If the main objective is to supply cheap power, a single purpose project is usually cheapest.

## Characteristic Features

Most SHP projects in tropical countries are in steep rivers with extensive amounts of rock, gravel and sand carried along in the water in a range of 200 to 2,000 tonnes/km<sup>2</sup> per year. Intake arrangements and construction of waterways along steep mountain valleys with tropical vegetation and overburden often represent significant cost items. Figure 4.6 shows a typical layout for a SHP project in a developing country.





Standardized designs for electromechanical equipment have been successfully developed for SHP in developing countries. Similarly, powerhouse and tailrace elements are relatively straightforward structures. In fact, comparatively few SHP projects have been implemented in full in developing countries and these have sometimes revealed deficiencies in the design of intakes, headraces and also penstocks.

The slope of typical mountain rivers in which SHP projects are situated ranges from 1:25 to 1:200. Such rivers can transport rock as well as finer material, and have a high sediment transport capacity, which will increase with increasing human activity and local scour. This must be borne in mind in the design of intakes. Major storage reservoirs are too costly, whilst smaller reservoirs will fill too quickly with sediment. Therefore, flushing of the intake pond is necessary, and some system of sand exclusion must be developed to protect the turbine from excessive wear. Because of the SHP characteristics, the headrace conduit will be relatively small but expensive to construct. It will also be vulnerable to erosion or rock fall. A closed, pressurized headrace conduit is therefore often recommended. A typical layout for a SHP project is shown on Figure 4.7 below.





For most small-scale hydro plants the headrace conduit must be placed on a steep hillside, which can lead to problems of access and rock instability. Careful attention must also be paid to the design of the forebay if it cannot be eliminated altogether. This is mainly because of the scouring problem arising from the spill of water and the flushing and drainage water. This can often be mitigated by employing a surge tank and added pondage rather than forebay. Discharges for most SHP projects vary from 0.5 to 3 m<sup>3</sup>/sec so that civil engineering works are relatively small. However, experience has shown a trend towards over-simplification and cost cutting. This in turn can lead to operational problems such as a washout of the headrace or penstock conduits and silting up of intakes within a very short time of commissioning.

#### Development Costs

Figure 4.8 below shows the total unit investment cost curve based on 35 SHP projects from Latin American countries. This has a correlation factor of 70 per cent.

Figure 4.9 shows the cost curve for electromechanical equipment. This is based on 25 cases with 97 per cent correlation.



Figure 4.8 UNIT INVESTMENT COST (TOTAL)



Figure 4.9 UNIT COST OF ELECTROMECHANICAL EQUIPMENT



Figure 4.10 shows similar cost curves for civil works based on 25 SHP project with a 60 per cent correlation factor.

An analysis of these costs shows that variation of the cost for electromechanical equipment is very small when head and discharge are known. However, as far as civil works are concerned, the cost is very much more difficult to predict and much more uncertain. Greater attention must therefore be paid to the physical conditions of each site. Figure 4.11 below illustrates graphically the variations in cost of the main components of a small hydropower scheme. On the basis of numerous projects carried out by Norconsult, the author estimates that given the approximate head and discharge, the cost for electromechanical works can be estimated to within  $\pm$  10 per cent. For the powerhouse, costs can be estimated to within  $\pm$  20 per cent. However, civil works, which are so difficult to predict are the critical factor in making an SHP project feasible or non-feasible.

Figure 4.10 UNIT COST, CIVIL WORKS



Figure 4.11 COST CHARACTERISTICS FOR SMALL-SCALE HYDRO PROJECTS

#### Assessment of Project Viability

The concept of Short-Run Marginal Cost (SRMC) and Long-Run Marginal Cost (LRMC) was introduced by the author. SRMC is the production cost of a marginal increase in energy supply into an existing system, whilst LRMC is defined as the marginal cost of a significant increase in the energy supply system over a period of years (say 20 years). In the case of exploiting the remaining hydropower resources in a river, the SRMC is the appropriate figure to use whilst, in adding power to an existing grid, the LRMC is more appropriate. In the development of a SHP scheme for an isolated system, the LRMC determines the correct cost for consumption of economic merit.

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The author recommends the following procedure for the efficient screening of viable and non-viable projects:

- Establish the objective.
- Establish an acceptable energy cost.
- Carry out desk studies of maps, photos and hydrology.
- List head, discharge, energy production, acceptable cost, cost estimates for electromechanical works, powerhouse and grid connection, on the basis of the desk study.
- Estimate acceptable civil works cost and then use an experienced team (two people) to check the civil works cost on site in detail. Also check transmissison costs.

This procedure will result in cheap, rapid and reliable screening and priority listing of SHP projects as a basis for the further detailed decision making and planning.

4.6 THE EVALUATION OF SMALL-SCALE HYDROELECTRIC PROJECTS FOR INTERNATIONAL FINANCING - THE CASE OF THE INTER-AMERICAN DEVELOPMENT BANK

> Mr. <u>GUSTAVO C. CALDERON</u>, Chief of the Non-Conventional Energy Section in the Inter-American Development Bank, addressed the Seminar on the evaluation of SHP projects for international financing and presented his own experience from his work with the Inter-American Development Bank (IDB) in Washington.

The Inter-American Development Bank was established in 1959 with its headquarters in Washington, to help accelerate economic and social development in Latin America. The Bank has 43 country members, 27 from the Western Hemisphere and 16 from outside the region. In its 26-year history the Bank has provided, or organized, financing for projects to a value of over US\$ 100 billion. Energy is the most important sector for lending and it takes more than one quarter of all loans. This is followed by agriculture, industry, environment and public health.

The Bank has drawn up guidelines for its operations in the energy sector for the period 1983-86; its efforts are concentrated as follows:

- Hydroelectric generation, transmission and distribution projects;
- Improvement of energy demand management;
- Development and utilization of non-conventional sources of energy;
- Formulation of plans and programmes for the energy sector;
- Strengthening technological infrastructure relevant to new and renewable sources of energy (NRSE).

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#### Small Hydroelectric Projects in Latin America

The Bank recognizes that small-scale hydropower is one of the most promising renewable energy sources where the technology is immediately available. The outstanding features of such projects are low cost-escalation coupled with high utilization, a potential for local construction and maintenance and minimum environmental effects. Although a modest start has been made in Latin America, the development of the enormous untapped small-scale hydroelectric generation potential in the region has not received the attention it deserves. Mr. Calderon drew the attention of the audience to the fact that one of the first SHP projects in Latin America, at Cali in Colombia, was commissioned in 1919.

The main problems encountered by the Bank in the development of SHP in Latin America have been the lack of resource data and the scarcity of managerial and engineering talent, especially at the local level. A loss of interest in SHP in recent years, because of the overall economic recession, has also been observed.

#### Evaluation of Projects

The Bank makes loans for specific projects and global loans for multiple work programmes. In its analysis of proposed specific projects, the Bank makes the following evaluations in its appraisal reports:

- a technical evaluation
- an institutional and financial evaluation
- a socio-economic evaluation.

The technical evaluation is designed to ascertain the general project feasibility and to determine and verify the scope and magnitude of the project. The institutional and financial evaluation ascertains the operational capacity of the implementing agency and the financial viability of the project. The socio-economic evaluation of the project takes account of social effects, including the effect of the project on income distribution, employment etc.

The Bank's experience has been that the information available for making these three evaluations was generally insufficient. This was particularly so for the technical aspects of the project. Engineering studies of topography, hydrology, geology and project layout were usually not sufficient for the Bank's appraisal. At the same time, the Bank recognized that they could not expect the same amount of technical detail as was produced for large-scale projects. The Bank was willing to accept the results of studies based on proven computer models, performed by experienced engineers. It is implicit that, thereafter, the detailed engineering design can be carried out as part of the construction process. To facilitate technical evaluation work, the Bank has developed a computer model for evaluation of the technical and financial aspects of a project. The institutional and socio-economic aspects, on the other hand, will still have to be evaluated in the conventional way i.e. independently of the model.

The IDB Model to Evaluate Small Hydroelectric Projects

The model evaluates each of the projects put forward, aggregates them if there is more than one, and carries out the appropriate sensitivity analyses. The following six separate sub-routines are then performed for each project:

- design and costing;
- cost escalation;
- debt financing;
- depreciation and tax credits;
- marketing and revenue;
- cash flow and analysis.

The process is shown on Figure 4.12.



Figure 4.12 PROJECT EVALUATION

The design and cost sub-routine contains all the project engineering features of the model, whilst the remaining five sub-routines comprise the financial routines.

#### Detailed Financial and Socio-Economic Evaluations

The model described above does not perform the financial analysis at the borrower or agency level or the socio-economic evaluation. For these evaluations the Bank uses standard guidelines already in use in the Bank for electric power and rural electrification projects, and for the Bank's small projects programme.

The Bank requires all loan applicants to provide feasibility studies performed or certified by experts with adequate background in the particular type of hydroelectric project or programme being proposed. It is also of particular importance that the project be considered as part of a rational overall plan for the development of the energy sector in the country.

Finally the speaker presented a proposed detailed methodology for the socio-economic evaluation of small hydroelectric projects, developed by the Bank from work already carried out on public works projects. The emphasis of the methodology is on getting approximate and usable results from the very limited data available in most developing countries.

## 5.1 REVIEW OF THE PRE-INVESTMENT CYCLE AND ESTABLISHMENT OF DEVELOPMENT CRITERIA

The Introductory Lecture on Decision-Making was given by Mr. ENRICO MALQUORI of ENEL (the Italian Electricity Board) as a guest speaker provided by the United Nations.

The speaker was concerned largely with establishing basic unit costs and guidelines for manpower inputs for the purposes of improved SHP planning. He presented a number of diagrams and slides to illustrate his contribution, and a paper on the Planning and Implementation of Small Hydropower Plants.

Mr. Malquori first gave a very brief description of the hydropower situation in Italy. In 1984 some 183 TWh was generated of which 25 per cent came from hydropower sources. Present installed capacity of ENEL is 13,800 MW.

#### Unit Costs

On the basis of an analysis of several small hydropower plants in Italy, the speaker showed that about 60 per cent of the total cost of a SHP project consisted of the civil works. For SHP projects from 200 kW to 3,000 kW the cost of civil works ranged from about US\$ 750 to US\$ 1,800 per installed kilowatt. The cost of equipment i.e. turbine, generator and control, was estimated to range from US\$ 350 to US\$ 700 per kW. The estimated cost of a transmission line per kilometre (15-66 kV) ranges between US\$ 25,000 and US\$ 40,000. The engineering cost was found to range from 5 per cent to 15 per cent of the overall project cost.

#### SHP Design Activities

Figure 5.1 summarizes the flow of major activities involved in the design of a SHP plant. For a project in the size range 200 to 500 kW about 70 man-months of design activities are required, while for a project of 1,500 kW to 3,000 kW about 140 man-months are required. These are summarized in the table below:

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Total:	70	146
Bid Documents/Procurement	10	26
Programmes/Cost Assessment	3	6
Detailed Design	16	44
Preliminary Design	9	22
Feasibility Review	4	8
Feasibility Site Survey	28	40
	200-500 kW	1,500-3,000 kW
	Man-months required	

## SHP Construction Activities

Figure 5.2 summarizes the flow of major activities involved in the construction of a SHP plant. It is estimated that approximately 2 1/2 to 3 years is required from start to finish of a conventional SHP project.

The speaker emphasized the need to base planning and design activities on previous national and international experience, on the use of standardized equipment and on the simplification of specification documents. These factors, in particular, help to reduce the overall cost of SHP projects.

## 5.2 SELECTION OF TECHNICAL SOLUTIONS FOR THE BUILDING OF SHP STATIONS

Mr. <u>KJELL SORLI</u>, General Manager for Engineering and Sales in Sorumsand Verksted, addressed the Seminar on technical solutions. Sorumsand Verksted is a major Norwegian manufacturer and exporter of electro-mechanical equipment, specializing in small hydropower.

The paper given by Mr. Sorlie was relatively technical, and has been greatly simplified in this version. The paper was divided into the following sections:

- Design trends
- Selection of turbines
- Comparison between turbine types
- Stability analysis and transient behaviour in water turbine plants.



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## Design Trends

For SHP projects it is very important to "think small". Standardization and simplification are important, and too detailed technical specifications for the supplier should be avoided by the consultant.

Simplicity, standardization, automation, remote control and low maintenance costs are key factors in successful SHP design. Although the main concept behind turbine design remains, the technology has developed rapidly. Welded steel has replaced cast iron and cast steel to a great extent and new materials like cavitation-resistant copper alloys have been introduced. It must be emphasized that it is not desirable to scale down large turbines for small hydro turbine designs.

The speaker summarized the main trends in turbine design as follows:

- there is a tendency towards a combination of tailor-made and standardized turbine parts, whereby the hydraulic parts of the turbine are tailor-made, while the "outer" parts are standardized;
- fully standardized turbines have been introduced for small projects under 1 MW;
- most small-scale Francis and Pelton turbines are arranged horizontally now, and this gives very compact and very economic operation;
- the use of corrosion- and cavitation-resistant materials is being widely introduced for guide vanes, runners, draft tube inlet turbine covers, etc.;
- lubrication-free bearings have been introduced;
- non-contact shaft seals have been introduced;
- the runner is mounted to the shaft by using the new oil pressure method, developed over the past 10 years.

## Selection of the Turbine

As turbine types have different operating ranges, the selection will depend on actual operating conditions. In most cases there will be no doubt as to which type is most suitable, but problems will arise in overlapping areas. In those cases, the choice of turbine has to

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be based on project requirements and total price evaluation. To obtain the best long-term solution, it is necessary to produce custom-built designs for the hydraulic part of the turbine while maintaining a high degree of standardization in the turbine itself.

#### Comparison of Turbine Types

A number of comparisons were made of different turbine types for different SHP conditions. Experience has shown that one or two jets are quite satisfactory on small-scale Pelton installations, and the runner diameter should be minimized in order to make the unit more cost-effective. However, for most flow/head combinations in SHP the Francis turbine with a very low specific speed is the most practical solution. It will generally be less expensive and require less space than a Pelton turbine. On a rated output of 2.5 MW and a rated head of 230 m, the price of a Francis turbine will be about 70 per cent of a Pelton's.

When compared with tubular turbines, the Francis turbine has several advantages. Francis turbines can be used on both high and low heads, whereas the practical limit of a tubular turbine is about 20 m. In the case of low heads, the Francis turbine will permit a much greater suction head than on a tubular turbine. At low speeds the tubular turbine will have a higher efficiency than the Francis turbine, but the Francis turbine will normally demonstrate better efficiency at about 90 per cent of full load.

## Stability Analysis and Transient Behaviour

The paper delivered by Mr. Sorlie went on to discuss in considerable detail the various calculations and methods employed to ensure the safe and satisfactory operation of a small hydropower plant. These included stability and transient behaviour analysis, the measurement of pressure response of a power plant with the surge shaft substituted by an air accumulator, computer analyses of small hydropower plants with different lay-outs (simulation), simplified formulae for assessing the stability of a power plant including surge shafts and/or air accumulators and the influence of high head Francis turbine characteristics on plant operation. These technical discussions were supplemented by a number of technical figures and diagrams.

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## 5.3 FINANCING, TENDERING AND CONTRACTING CONSIDERATIONS

Mr. <u>PAUL WIEBE</u>, Consultant to the United Nations Department of Technical Co-operation for Development (UNDTCD), addressed the Seminar on the development aspects of SHP, that is finance, tendering and contracting. Mr. Wiebe examined these three subjects in turn.

## Financing

Most major projects in developing countries, including SHP, are in the public sector. In all cases their development needs a clearly identifiable sponsor or promoter. Usually, in developing countries, the sponsor is a government or a local or regional public utility.

In some recent developments, SHP projects have been organized at community level. In north-west Pakistan, the Directorate of Small Hydel Stations has organized SHP development most successfully at local community level. Private development is also possible, and in Peru, the Government permits mining companies to develop their own SHPs. In the USA, Federal Government support is available through special legislation (FERC) for development of SHP by private companies.

Conventionally, financing of SHP development has been carried out on either an agency or project basis. For agency lending, lenders and borrowers recognize that lending becomes an act of faith in which detailed financial analysis is meaningless. The funds are allocated on the basis of the creditworthiness of the agency taking up the loan. Thus, financing specific SHP within this framework becomes a matter of government priorities, based on relative economic and social factors. Project financing, on the other hand, is a newer development. It is based on the cash flows and earnings of the project as a source of funds for repayment. The assets of the project act as collateral for the loan. This may allow important projects to proceed while the credit of the sponsor is overextended. Project financing can therefore provide a number of benefits for the corporate developer, but implies higher risks for the lending agency, which, in turn, are reflected in higher interest rates. Such rates have tended to range from 1/4 per cent to 2 per cent above prime corporate lending rates.

Before deciding upon the type of credit which has to be used for the SHP project, a number of questions have to be answered. Will this be the first electrification of an area? Is there a ready market for the electricity? Is there a fee collecting agency? Can other

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elements be incorporated into the project viz. irrigation, roads, drainage, etc.? It will also be important to determine whether the local community can contribute to the project. Each project has a defined loan capacity and the loan must be structured and its advantages identified to match the criteria of the lenders. It is important to obtain professional and independent advice on potential sources of financing, which can be very varied.

#### Main Financing Types

The speaker then described the main types of financing available for SHP projects and programmes in developing countries. These were identified as:

- Bank credits
- Export credits
- Private placements
- Development bank loans
- Bilateral aid
- Co-financing.

The most frequently arranged energy borrowing facilities are bank credits. For project financing this will involve a set of documents, including completion agreements, technical agreements and firm sales contract agreements. Letters of credit from the bank can be particularly useful in the early stages of SHP development, enabling construction to begin while detailed financing arrangements are being finalized.

Export credits are used by many countries to support their industrial companies by offering credit facilities. Interest rates are covered by consensus terms, agreed upon by industrialized member nations of OECD. Rates depend upon the borrower's country economic rating and the currency of the loan. Export credits are often available for up to 85 per cent of the value of the export portion of the contract.

**Private placements** from insurance companies and other financial institutions are often an attractive source of funding in some countries. These have a fixed interest rate for a long maturity.

The international development banks, such as the World Bank and its affiliates and the Regional Banks, have built up a long and successful record of assisting developing countries in implementing SHP and other projects. The viability and potential of projects is carefully reviewed and appraised by the Banks' own teams of experts. Funds can only be used to meet construction or procurement costs. Procurement is done by international tender.

Bilateral aid is provided on a direct country-to-country basis, and countries like Norway, Sweden, Denmark, Canada, Germany and USA have developed very substantial bilateral development assistance. The development assistance agency in the developed country is responsible for working out an acceptable assistance programme, together with the authorities in the recipient country. Some countries require so-called "tied aid", whereby the receipt of bilateral aid is contingent on using services or products from the donor country. Other countries do not require a strong tie. Increasingly, international development banks and bilateral aid agencies are co-operating with each other to fund projects. This enables those agencies to diversify their support among countries, and projects such as SHP, where there is a great increase in the demand for finance. With participation financing, the earlier maturities of a development bank loan may be sold to a commercial bank. Under joint financing, the development bank and the co-financing institutions each fund agreed portions of elements of the project. With parallel financing, separate elements of the project are identified. The development bank funds certain elements, the co-financiers finance others. As many as six different development banks, or bilateral aid agencies, have recently been engaged in one SHP project in West Africa, and in such cases the client needs the assistance of a promoter, to stir up interest in financing different elements of the project.

## Tendering and Contracting

Suitable packaging of project elements for tendering and contracting can be important for the timely and efficient development of SHP. How could tendering and contracting packages be decided? In the first place, all contract packages and supply items which can be purchased and manufactured locally must be defined. This helps to reduce the foreign exchange element and increases local commitment. Secondly, it is necessary to define those contract elements where there is a shortage of local experience. The use of outside expertise is often necessary to overcome concerns of financing agencies on cost overruns. Thirdly, the number of contracts and contractors has to be reduced, and contracts should be combined or,

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at least, co-ordinated wherever possible. However, it has to be borne in mind that civil works may be divided into different contracts, where very different activities and types of equipment and techniques can be involved.

As far as the tendering of construction packages is concerned, these should be separated into foreign and local components. Then calls for bids may be open or may require prequalification. A co-operative environment between the SHP owner and the contractor is essential for an effective project management, as both parties have obligations to one another.

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## 6.1 THE CONSTRUCTION CYCLE AND SCOPE FOR LOCAL PARTICIPATION

Mr. <u>ANTHONY BROMLEY</u> of the Division of Industrial Studies of UNIDO presented a paper describing the experience of Malaysia in mini-hydro civil works design and construction. Twenty-two sites have already been developed and study and design work on a further 82 sites has been completed. There is therefore a considerable amount of information available for reviewing the approaches to the design and construction of small-scale hydropower schemes used in this case.

In developing a design, main emphasis is placed on simplicity, reliability and cost-effectiveness. Local participation is intended to achieve a sound project consistent with high power plant availability and low maintenance costs. This approach requires clear recognition of the functioning of each component part of the scheme and of the design criteria to be met so that a satisfactory operational performance can be assured.

Bulky materials of construction should be available locally. Indeed, site selection should aim at identifying locations where suitable bulk materials can be found and also where ready access for the construction effort can be secured. The construction work should be so planned as to cause least disturbance to the environment, minimal excavation of the ground and least removal of trees and other natural ground cover. Erosion and scouring of the river bed should be protected against. Many developing countries suffer from strongly seasonal variations of run-off and the project design must therefore cater for an adequate overflow or flood relief capacity. The flow-diverting structure must be able to resist the forces acting on it under flood flow conditions. An attendant danger of high flood flows is the carry-over of solids in the river water; much care needs therefore to be devoted to the design of a settling or stilling basin, or of a desander, and to the purging arrangements needed to ensure satisfactory operation of any settling devices installed.

The water conduit and penstock are probably the most expensive items among the civil engineering components of a hydro scheme of small size and their planning and design calls for much care. Each solution is specific for the local conditions and undue generalization of design criteria is not helpful. The same applies for the powerhouse design which has to be adapted to the local topography as well as the available hydraulic head and the consequent type and arrangement of the turbine.

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The overall construction cycle must also be appropriate to the local conditions. These involve frequently difficult and hazardous access to a remote site, and development of this site in virgin territory devoid of all facilities. Cost considerations make it imperative to maximize the use of local labour and to minimize the need for imported skill. All the same, the local labour force needs to be trained for the specific work to be carried out, however simple the tasks to be allotted may appear. The construction plan must allow for such training.

Construction equipment should be of straightforward and conventional design and should as far as possible be of standardized type as used elsewhere in the country's civil engineering construction industry. Basic equipment needed is likely to include cement mixers, air compressors, bulldozers, welding machines, concrete vibrators and portable generators. Transportation facilities to bring construction materials to the site must be appropriate to the local terrain but equipment of the right type will no doubt also find use elsewhere in the country.

Adapting the design to the local environment is likely to minimize import requirements for construction materials and hence reduce the need for elaborate transport arrangements. Construction materials must however be carefully selected to ensure that they can stand up to the local conditions of temperature, solar flux, humidity, abrasion and erosion as well as the operational stresses imposed on them and to a certain amount of rough handling which is inevitable at a remote and undeveloped site staffed largely with unskilled labour. Construction methods will likewise have to be adapted to local circumstances, for example by avoiding rock blasting because of security reasons or major river diversions because of the potential loss of downstream benefits. Every case needs to be considered on its own merits.

#### 6.2 CONSIDERATIONS ASSOCIATED WITH LOCAL MANUFACTURE OF ELECTRO-MECHANICAL EQUIPMENT

Mr. WILLIAM TANAKA, the Head of the Development and Transfer of Technology Branch of UNIDO, presented an outline of the role of that organization in encouraging local manufacture of electro-mechanical equipment for hydropower schemes in developing countries. UNIDO provides mainly technical assistance, advice and support to these countries and can function only where a formal request for such assistance has been made. UNIDO has an extensive investment promotion programme which is strongly supported by Mr. Tanaka's Branch. A 7-volume handbook for advising local firms on approaches

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to local manufacture has been produced and a number of other publications are also available offering information and advice to potential manufacturers in the developing countries; this literature includes publications on the economic appraisal of industrial projects which is a subject of particular importance in the formative stages of a manufacturing plan. UNIDO is also very active in identifying the potential for manufacture of equipment and components under license.

Mr. Tanaka gave examples of UNIDO's experience in promoting manufacture of electro-mechanical equipment in Pakistan and Nepal. He also referred to previous discussion of this subject at hydropower seminars in the Far East. Countries interested in studying more closely in what way local manufacture might best be introduced to support their hydropower development should in the first place undertake a detailed review of the potential scope and prospects of such an activity. UNIDO is available to offer advice and assistance.

During a lively discussion on Mr. Tanaka's presentation, participants confirmed that the experience gained by several of the developing countries in the local manufacture of electro-mechanical components had been encouraging. Successful local participation had also been recorded in the Philippines and in Indonesia. There was a danger, however, to rush into industrialization uncritically and to set up ventures which ultimately had to close down. A careful market appraisal was needed in every case.

Speakers suggested that, in some cases, the establishment of a local capability for repair and maintenance work rather than manufacture was more important. This view appears to be reinforced by the lack of adequate maintenance facilities experienced by a number of developing countries and the urgent need to set up such facilities in order to keep the power plants in satisfactory operation. DTCD, for example, has had a number of requests for assistance in establishing maintenance workshops and training local technicians in their use. Such workshops can ultimately be turned over to the manufacture of simple components.

Some participants thought imported second-hand equipment might provide a useful start for a local industrial activity but others feared there might be some objection to the use of such equipment, particularly if there was an inadequate transfer of technology to accompany the imported equipment. It was important that the recipient country should be able to use the equipment effectively and with good results, producing reliable components made to acceptable tolerances.

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Co-operation with equipment suppliers and manufacturers was considered essential to secure adequate technical support and avoid adopting outdated technologies. It might also encourage the formation of regional markets which could greatly enhance the scope for local manufacture. 7.1 OPERATION OF SMALL HYDROPOWER SCHEMES AND THEIR INTEGRATION INTO UTILITY SYSTEMS

This paper was delivered by Mr. <u>NILS FOSSEN</u> of Hafslund Engineering of Norway, on behalf of Mr. <u>Nils Juell</u> of the same company, who was indisposed.

The speaker presented several aspects of the operation of SHP projects, i.e. development phases, programmes for consumption, sales policy, SHP in isolated networks, networks with more than one station and SHP stations connected to a large grid. The bulk of the paper was devoted to the operational aspects of isolated SHP schemes, rather than schemes connected to a main grid.

#### The development of SHP

SHP projects develop in a systematic manner in a clearly identifiable sequence. Firstly, an isolated SHP scheme is built to serve a single consumer or group of consumers, connected by a local distribution network. Additional SHP stations are then connected to the local network. Two or more local networks are then interconnected by transmission lines, and finally, the local network system is connected to the regional or national electricity grid. The main factor concerning the operation of a SHP station is whether it is on an isolated network or whether it is connected to a larger grid.

## Electricity Consumption Development

Initially, in an area which has been newly electrified, consumption will be relatively low. SHP schemes normally use runoff from small catchment areas, where storage capacity is limited. Production Capacity of the SHP station will therefore depend directly on the available water flow which can be seasonal.

Annual consumption therefore often does not correspond to annually available supply, and this results in poor utilization of plant capacity and water resources. This is a feature of small isolated schemes. In addition, initial power demand may be so low that the power station has to be closed down in order to avoid cavitation on the turbine blades due to excessively low water through-put, or an artificial load imposed on the plant. It is therefore essential to initiate a programme to develop the consumption of electricity in

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the community, and such a programme should form an integral part of the overall SHP development project. Consideration should be given to development of off-peak uses, such as: pumping for fresh water supply and irrigation, refrigeration and cold-storage facilities for agricultural and food processing, heating of water and the introduction of electric storage stoves for cooking and space heating. An educational programme demonstrating the uses and advantages of electricity should be developed. Such a programme should also include information on the dangers and costs associated with the use of electricity.

#### Electric Sales Policy

In introducing electricity to an area, a sales policy which optimizes the use of energy should be adopted. Many countries have adopted a flat rate for the whole country. However, there are very strong arguments for subsidizing energy consumption in the initial stages in order to introduce and increase electricity supply, especially in remote areas. Rates for thermal power are usually designed to make consumers pay for each unit, and so reduce consumption to a minimum. However, with hydroelectric power, where Operating costs are virtually nil, rates should reflect this fact and should encourage the use of electricity rather than let it go to waste. In Norway, rates have gone through a series of developments. First, a straightforward cut-off rate was used, whereby supply to the subscriber was cut if consumption exceed a certain level. Then more sophisticated systems were introduced in order to increase the use of energy. Now, where virtually all energy comes from hydropower, rates have been rationalized to make maximum use of all available power. It seems likely that each rate was appropriate for its particular stage of development, and it is important that rates should reflect the stage of development in demand and consumption which society has reached.

### SHP in Isolated Areas

Norway's experience shows that consumption and demand increase rapidly after the installation of SHP in an isolated area. It is frequently necessary to ration power supply for consumers. In order to maximize production capacity, full use must be made of available hydrological data. However, because few SHP stations have reservoir storage capacity, the scope for major increase in production is not great. Hydrological models and analyses have recently been used to improve operation of SHP plants. It is therefore very important to prepare and apply operational procedures for the plant which define the way it is to be operated so as to make maximum use of the river flow and relate its output to the forecast power demand. When not enough water is available, it may be necessary to shut down the plant for limited periods. If there is no storage available, load shedding according to a priority plan can be undertaken. If no disruptions in supply can be tolerated, diesel units can be used as back-up supply. This is especially relevant in areas where the river flow varies widely over the year.

The speaker then gave a series of examples of operational procedures for SHP stations under different conditions.

### Operation of a Network with more than one SHP Station

Supply reliability increases with the installation of more than one SHP station in a local network. Maintaining a continuous supply becomes less critical for each individual power station. The operation of each plant should be optimized in accordance with the needs and characteristics of the system as a whole.

In a local network of several SHP power stations, an operating strategy for the whole system must be developed, defining which units will operate when, and the distribution of production between the units. Factors governing this will be the resource costs of each unit, water availability for each unit, the differences in efficiency between units, costs associated with start and stop of each unit, restrictions on operational reliability and restrictions on maintenance. The resource cost of a thermal power plant is the price of the gas, oil or coal burnt. However, the resource cost of water and a hydropower scheme is a more complex concept. The water resource cost can be defined as the future expected value of the water, and will depend on how future water flow and demand develop.

## Operation of SHP connected to a larger Grid

When a SHP project is linked to a larger regional or national grid, production is no longer limited by the local power demand. The main operational criterion will therefore be optimum use of available water. If the SHP plant has storage and is supplying a grid which contains thermal power that hydro can replace, the more expensive thermal power should only be used during peak hours.

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#### Operational Organization

In rural areas, the most efficient approach is to use the same organization to operate both the SHP plant and the local network. This organization will be responsible for operation, inspection and simple maintenance, and should be linked to a larger centralized organization, if possible, which can provide the resources for more complex repairs and maintenance. The main tasks for a local SHP organization will consist of the following:

- inspection of dams and waterways
- cleaning of trash racks and water intakes
- reading of meters, water levels and meteorological observations
- inspection of temperatures, oil levels and machinery in the power station, lubrication, etc.
- inspection of electrical equipment
- start/stop of the units
- operation and inspection of the local distribution network.

Operational personnel should, of course, be recruited locally and have participated actively in the erection and commissioning of the station.

# 7.2 TRAINING AND MAINTENANCE ASPECTS IN CONNECTION WITH SHP DEVELOPMENT

Mr. ODD HOFTUN, practising hydropower engineer with the United Mission to Nepal (UMN) addressed the Seminar on aspects of training and maintenance in connection with SHP development.

Mr. Hoftun based his submission on personal observation and many years of experience with small hydropower projects in Nepal, ranging in size from a few kilowatts to 1 megawatt. His paper dealt with maintenance and training, ownership and management of SHP projects and with the overall administration of SHP development in Nepal. Finally, the paper focussed on the problems and potentials of SHP-based rural electrification in developing countries like Nepal.

#### Maintenance, Training and Operation of SHP

The maintenance and training aspects of SHP must be taken into account at the very beginning of a project. However, experience from Nepal shows that this has largely been overlooked. Governments, consultants and financing institutions seem to have ignored maintenance and training within the SHP sector for various reasons.

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Because SHP projects are small, the apparatus for operations and maintenance should also be small, and operation and maintenance should be carried out by the same persons and not artificially divided; one organization should handle both generation and distribution.

If there is trouble in the powerhouse the line crew can be called in to help. If a line has been damaged by a storm, the powerhouse operators can be called in to help.

It is important to point to the difference between a SHP project feeding into a larger grid in an industrialized country, where the purpose is to provide the highest possible amount of energy for sale to a larger system, and a SHP system for rural electrification in a developing country like Nepal. In the case of a SHP project feeding to a grid, the project is either feasible in financial terms or not, once the technical problems have been solved. The project will then be built or not, depending on the results of the evaluation. However, a small hydropower project to introduce rural electrification in a country like Nepal has to be considered very differently. Because the market and the ability to pay initially is so small, SHP must be treated as part of an integrated programme, where electricity will interact with other inputs to promote economic development over a long period of time.

Designs of operation and maintenance systems in Nepal are therefore very different from those in Norway. In Nepal, which is still in the early stages of electrification, consumers are willing to accept a certain amount of irregularity in the power supply due to repairs and maintenance. It will take time to educate local people in the use and benefits of electricity. People slowly come to depend on electrification, and demand will slowly outstrip supply. However, this process will take many years to develop.

# The Cost Factor

Because of high costs, the future of small-scale hydropower in Nepal is not good. The cost of Government-sponsored projects exceeds US\$ 4,000 per installed kilowatt, and operating costs are equally high. The guestion is whether the initial investment as well as operating costs can be reduced by a different approach during the planning and design stage?

It is important to remember that SHP should be small in every way, small in investment cost, small in organization and staff, small in operating budget, etc. This simple and obbious fact is too often forgotten. At the same time it must be recognized that proper

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maintenance implies an expense now for something not absolutely essential at the moment. Sufficient long-term budgetary provision must be made for maintenance.

#### Ownership Structure and Management of SHP

Three types of ownership are possible for a SHP plant in Nepal. These are Government, community or private. So far, the pattern in Nepal has been for Government to own and operate SHP plants, although recently individuals and companies have been permitted to generate, distribute and sell electricity from SHP plants of up to 100 kW. By the very nature of SHP with its local isolated character, it seems that central Government is not suited to operate such plants. Plants are so small that they cannot afford a large, centralized bureaucracy, and as revenues usually go into central Government coffers, there is little incentive to achieve efficiency or increased production from each individual project.

Ideally SHP projects in countries like Nepal should be locally owned and managed. Local interest makes for more efficient and greater production. Surplus income can be used for operation and maintenance, or to bring rates down for the overall benefit of the community. SHP projects can also be integrated into an overall community development programme if they are locally owned and operated. Where there is a lack of good community leadership talent, private ownership may be a workable alternative. However, it is important to recognize that Government does have a role in SHP. It should be responsible for developing technical standards and regulations. It should be able to offer financial assistance and soft loans, and technical assistance to local communities or for private SHP schemes.

# Simplicity in Design

The need for simplicity in design of SHP projects cannot be overemphasized, and the Norwegian example is a good one for many developing countries. Over the past 80 years, Norway has developed many extremely simple and therefore cheap SHP plants, which were also easy to operate and maintain. They have been of great benefit for the economic development of the districts in which they are situated. In order to cut costs, local experience and local consultants should be used, and one should be prepared to use very simple intake structures, etc., which can be replaced by local labour where necessary. In many cases, maintenance costs for SHP will be rather high, whether the structure is simple and cheap or sophisticated and expensive. Simplicity should also be the keyword in the design of electromechanical equipment. Experience from the early plants in Norway and from operation in developing countries today is that the simpler the equipment, the better it will perform. Quality combined with simplicity seems to be the answer. As a back-up for such simple and good quality equipment and design, it has been found that some sort of central service facility or workshop is necessary to support local unqualified personnel in the maintenance of equipment. Such a central service facility could be operated by a private firm which signs contracts for maintenance of individual SHP projects. The firm should provide qualified staff, undertake repairs of equipment and carry a comprehensive stock of spare parts.

## Personnel Recruitment and Training for SHP

Trained personnel for SHP is required at two levels: on the one hand to build up a small but highly qualified technical staff at central Government level for the planning and overview of a national programme for SHP development and, on the other hand, to give advice and support to individual SHP projects.

An SHP engineer needs a strong and wide-ranging academic background, as well as practical SHP experience. Unfortunately, SHP does not seem to have the glamour and prestige of other types of engineering and it is difficult to obtain the kind of qualified all-round engineers which the discipline needs.

On the other hand, SHP development needs a large number of staff at the project site. Because of the shortage of trained personnel in a country like Nepal, the number of technically trained staff must be kept at a minimum and educational requirements should not be set too high. This is possible when using simple designs and equipment as recommended above.

Therefore, site project staff should as far as possible be trained on the job, and for the sake of long-term dependability they should be recruited locally, as was the case in Norway in the early development of SHP 80 to 100 years ago.

Recruitment should begin as soon as construction starts. Local persons should be selected and trained on the job during the construction and erection period. The staff will eventually become powerhouse operators, linesmen, dam attendants and semi-skilled electricians, but should be versatile and know a little about everything, so that they can fill in for one another. This on-the-job training should initially be handled by the contractors responsible for the civil works and the installation of the plant. It could be continued by a central technical facility, providing qualified instructors for on-site instruction or short-term courses off site.
## 8.1 BACKGROUND

Representatives from 25 developing countries attended the Seminar. Before arriving they were invited to submit Country Papers, describing the development, present status of, and future plans for, small-scale hydropower in their respective countries. The response was excellent, and 21 different Country Papers were delivered.

The range of experience and expertise covered in those papers was enormous - from the small West African state of Liberia, with a population of 2 million, to the People's Republic of China, with over 1,000 million people. In Liberia, a survey of the country's potential hydropower resources had just been completed and some of the country's first small-scale hydropower projects are now under construction. In China, on the other hand, over 78,000 small-scale hydropower projects had been constructed by 1984, providing about 33 per cent of China's total installed, hydroelectric capacity. The Country Papers therefore represent a huge body of knowledge and experience which can be drawn on and indicate the enormous scope which exists in the small-scale hydropower field for Technical Co-operation between Developing Countries (TCDC), which the United Nations system has done so much to foster and promote in the recent past.

A total of almost 250 pages of Country Paper contributions were submitted from the following countries:

Bolivia, Burundi, China, Honduras, Indonesia, Jamaica, Lesotho, Liberia, Malawi, Malaysia, Mauritius, Mozambique, Nepal, Nigeria, Peru, Philippines, Sierra Leone, Sri Lanka, Tanzania, Thailand and Uganda.

This Chapter sets out edited and abbreviated versions of each of the 21 country papers submitted.

### 8.2 BOLIVIA

by Osvaldo E. Quiroga, Engineer, National Electricity Authority of Bolivia.

Bolivia, with 6 million people, has a very low population density. About 55 per cent of the population live in rural areas, but only 4 per cent of the rural population has access to electricity. Less

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than 2 per cent of the country's economically feasible hydropower potential has been developed.

Hydroelectric power in Bolivia was first developed over 80 years ago, mainly for private mining companies and urban consumption. However, development has been slow, because of the general poverty of the country. Today, Bolivia has some 65 small-scale hydropower plants of under 5 MW.

Bolivia now places considerable faith in UNDTCD's recent preliminary project inventory which has identified 125 potential sites, with a total potential of about 58 MW. It was argued that small countries, like Bolivia, require international support in convincing financial institutions that small-scale hydropower is socially, economically and financially viable

# 8.3 BURUNDI

by Audace Ndayizeye, Adviser, Directorate-General of Energy, Burundi.

Average electrical energy consumption per capita in Burundi is 14 kWh (c.f. Norway, 22,325 kWh). Burundi, with a population of 4.5 million, has one of the highest population densities in Africa. Because of its land-locked situation, Burundi is highly dependent on imports and obtains much of its electricity from Zaire. The country's installed capacity is 23.2 MW, of which 40 per cent comes from hydropower sources.

Burundi's hydroelectric potential is estimated at 1,371 MW, of which 50 per cent is shared with other countries. At least 41 potential sites have been identified as economically and technically feasible for development. Small-scale hydropower was first introduced to Burundi by the religious missions in the 1930s, but now Government takes an active interest in promoting SHP through its rural development programmes. Some 10 small-scale hydropower plants are projected, to a total value of US\$ 66 million, and some US\$ 2 million has been allocated to micro-hydropower development.

Mr. Ndayizeye identified the following as the major problems, facing development of small-scale hydropower in Burundi:

- lack of experienced personnel in small-scale hydropower
- difficulties in raising funds for project implementation
- delays in spare parts and equipment delivery, because of the country's location.

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Nonetheless, hydropower is probably the country's most promising future source of energy for rural development and Burundi will continue to promote its development.

#### 8.4 CHINA

by Zhao Zengguang, Chief Engineer, Dept. of Rural Electrification, Ministry of Water Resources and Electric Power, China.

In China, precipitation decreases gradually from south to north, so that the main hydropower resources are in south China. It is estimated that about one quarter of all the counties in China can rely on small-scale hydropower to solve their primary electrification requirements. Small-scale hydropower has been very actively encouraged in China since its first establishment in 1912.

By 1984, over 78,000 small-scale hydropower stations had been established, with a capacity of 8.9 GW or about one-third of the total installed hydropower capacity in China. One-third of all counties rely primarily on small-scale hydropower for their energy and sell about 3 GWh to the State grid.

Small-scale hydropower is an important component of the rural energy picture in China and has been of particular significance in developing the mountainous regions of the country. Certain provinces, e.g. Zhejiang Province, have benefitted financially from small-scale hydropower through extensive sales to industry. Small-scale hydropower was found to be instrumental in developing industry, mechanizing agriculture, conserving farm land, accumulating funds locally, increasing socio-economic development in mountainous regions and protecting forests by reducing fuelwood consumption.

Implementation of small-scale hydropower development is carried out at county level (there are 2,300 counties in China) and the county administration's functions are to provide load forecasts, select power sources, achieve balance between power and energy supply and demand, arrange the grid network, carry out economic and financial feasibility studies and make annual recommendations for implementation.

In the development of SHP projects, China has placed strong emphasis on administrative decentralization to the counties and has adopted a policy that "He who builds will also own, manage and benefit from what the station produces so as to protect the people who construct it." China has learned many lessons from its development of SHP. Projects should benefit those who build and operate them. Financial incentives and assistance has to come from Government. Equipment installation and manufacture should be standardized to reduce costs. SHP projects should be interconnected wherever possible to make use of seasonal variations in regional water supplies. Training at the local level is essential. Finally, China regards SHP as a strategic measure to use electricity in rural areas and to exert a direct impact on the rural economy. The Chinese experience shows that SHP projects can have a sizeable effect on local socio-economic conditions.

#### 8.5 HONDURAS

by Mauricio Mossi Sorto, National Electricity Company of Honduras.

The National Electricity Company of Honduras has established a special office for Small Hydroelectric Projects, as part of its overall rural electrification programme which began in 1970.

Two sets of inventories of small-scale hydropower potential in Honduras are currently carried out. These are an inventory of potential sites of between 5 MW and 30 MW on the basis of different river basins and an inventory of sites in the potential range of 500 kW to 5,000 kW (these are mainly isolated sites in remote locations). Numerous potential projects have been identified through these inventories and are at various stages of planning, design and implementation. The Small Hydroelectric Projects office also provides technical assistance to coffee plantations and other private developers wishing to develop small-scale hydropower. The office offers services in identification of SHP sites --- these are usually in remote rural areas, which are unlikely to be connected to the National Grid for many years --- studies of the power market, basic design and assessment of the various cost factors. Finally, an economic evaluation is undertaken.

Honduras's long-term goal is to extent SHP schemes to all areas which are not connected to the National Grid and which are unlikely to become interconnected in the foreseeable future.

#### 8.6 INDONESIA

by Hartoyo Notodipuro, Director, Electric Power Research Centre of the State Electricity Corporation of Indonesia.

A total of about 30 MW in installed capacity has been built in Indonesia in the form of small-scale hydropower. An additional 10 MW is under construction. This is low in relation to the estimated potential.

In 1983, the State Electricity Corporation of Indonesia (PLN) completed a Hydropower Potential study, which identified a total potential of 1,340 MW capacity which can be developed in units of under 5 MW. A total of 291 potential SHP sites were identified on the 14 main islands of Indonesia. With the help of the Asian Development Bank, Indonesia is currently undertaking a study to establish which of these sites is located near potential demand centres. This study includes carrying out feasibility studies of 10 mini hydropower schemes.

Small-scale hydropower is an important instrument in Indonesia's energy policy, and will be used to create jobs in rural areas, to reduce urbanization and promote local opportunities in consulting, contracting and manufacturing for small hydropower development.

With the completion of the national Hydropower Potential Study, Indonesia is now concentrating on locating SHP projects which are not capable of being served by the national grid, are close to potential load centres, have acceptable geological and topographical conditions and will not disturb the natural environment. A total of 52 MW of small hydropower projects are therefore planned for implementation during the fourth Five-Year Development Plan of Indonesia.

A major effort is being made now to decentralize the planning and implementation process for SHP in Indonesia and a series of manuals and training routines for local people are currently being worked out for use in identifying and developing SHP projects in remote rural areas.

Indonesia has considerable capacity for design, engineering and construction of SHP projects, but foreign financing often imposes conditions, which obliges Indonesia to use overseas consultants and contractors in partnerships with local firms. Indonesia is also very eager to develop local manufacturing capacity for SHP. The country already has the capacity to produce low and medium voltage cables, bare conductors, distribution transformers, distribution and control panels, switches, metering equipment, low capacity generators, small-scale turbines and other auxiliary equipment. Finally, Indonesia is making a serious attempt to co-ordinate the efforts of all the different institutions which are engaged in small-scale hydropower development in the country.

## 8.7 JAMAICA

by Ainsworth N. Lawson, Ministry of Mining, Energy and Tourism, Jamaica.

Jamaica has few indigenous energy resources and currently spends 45 per cent of its net annual foreign exchange earnings on the import of fuel oil. The country is trying to reduce oil consumption through conservation measures, to develop peat resources and to start using coal-fired power plants.

The first hydropower project in Jamaica was built in 1898, and the five existing plants were built between 1945 and 1959. The total generating capacity in Jamaica is 431 MW while the hydropower capacity is 9.3 MW.

A recent survey of the hydro potential carried out by the Ministry of Mining and Energy has identified a total of 23 different projects recommended for implementation over the next 10 years, with a total generating capacity of about 118 MW. These sites are found throughout Jamaica, along the central ridge of mountains. Access problems can cause considerable cost increases in civil works. A number of project packages have been assembled by the Jamaican Government, for consideration by financing agencies and bilateral funding organizations. However, because of the country's precarious external debt situations, only the most attractive financial packages on offer can be considered by Jamaica.

# 8.8 LESOTHO

by Letlafuoa T. Molapo, Lesotho Highlands Water Project Unit, Lesotho.

Lesotho's energy situation is dominated by the Republic of South Africa, which completely surrounds the country. Lesotho has very considerable water and energy resources, but their development has always to be compared with the continued import of very cheap electrical energy from South Africa.

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An energy survey in 1983 showed that, although Lesotho is highly dependent on traditional non-commercial fuels, like firewood and cattle dung, these fuel sources are almost depleted. The Government is therefore focussing on the country's hydroelectric potential, which is not yet exploited. Today, about 99 per cent of all electricity used in Lesotho is imported from South Africa. The peak demand amounts to about 30 MW. Two major multipurpose projects, the Highland Water Scheme and the Oxbow Scheme, are under planning for supplying South Africa with water and electricity. Some six small hydropower schemes have been identified as priority projects. Five of these have been financed and will be implemented with Norwegian and French assistance during 1985 and 1986.

Certain local factors and conditions influence the development of SHP schemes in Lesotho. As the country has no SHP projects yet, electricity rates are still geared to the large and prosperous consumers. This situation will have to be reviewed as new projects are developed. Lesotho's climate, with distinct wet and dry seasons, makes it necessary to provide large storage reservoirs, and this implies that feasibility studies should contain provision for exploratory drilling. The cheap electricity, imported from South Africa, is also an important factor in Lesotho's electricity supply planning.

Lesotho has limited SHP experience as no scheme has yet been built in the country. There is ample scope for employing local civil works contractors on SHP schemes in Lesotho so that this component need not be imported.

## 8.9 LIBERIA

by R. Emile Rhinelander, Ministry of Lands, Mines and Energy, Liberia.

A survey carried out in 1982 by the UNDTCD, on behalf of the Government of Liberia, showed considerable potential for the development and implementation of SHP schemes. The investigations were concentrated on the country's largest rivers.

The country paper examined in detail the implementation of the Yandohun Small-Scale Hydropower Project in north-west Liberia, which is completed and due for commissioning in July 1985.

The project, which received assistance from the United States Agency for International Development (USAID), was regarded as a serious attempt to decentralize decision-making, by involving local people in all stages, and to make maximum use of locally available energy resources. The installed capacity of the Yandohun project is some 35 kW, which is intended to serve a small village of 550. In addition, it is hoped to stimulate the development of small craft industry, which will be able to take up any available surplus power. An interesting aspect of the project has been the involvement of the local village community in the financing and construction of the project. The total cost of the project has been estimated at US\$ 132,000 of which USAID paid US\$ 95,000 (including the cost of the turbine), the Government of Liberia paid US\$ 20,000 and the villagers themselves US\$ 17,000 of which \$13,000 was in kind (labour and materials) and US\$ 4,000 in cash collected by the community.

The Yandohun project is an interesting example of how a very small project can be installed in a remote community and made to function by its active involvement.

#### 8.10 MALAWI

by Thomas Uko, Chief Engineer, Electricity Supply Commission of Malawi.

Malawi's electrical energy network is well developed through its Rural Electrification Project, funded by the African Development Fund. This has led to an interconnected power system, which has an installed capacity of 148 MW of which 124 MW is hydro and 24 MW thermal plant. The hydropower schemes are based on the Shire River power stations, which are located to the west of the city of Blantyre in the south of Malawi. However, centres in the Karonga and Chitipa Districts in northern Malawi are unlikely to be connected to the national interconnected system in the future although a 1981 UNDTCD survey identified a number of potential SHP sites in these two districts. A number of detailed studies have been made and a number of project packages have been presented to the Southern African Development Coordination Conference (SADCC) for financing.

Malawi is particularly keen to develop its small-scale hydropower resources with the immediate view to supply electricity to these centres, which are remote from the interconnected system. The development of small-scale resources will reduce Malawi's dependence on imported energy sources, resulting in important savings in foreign currency.

# 8.11 MALAYSIA

by Rahimuddin B. Baharudin, Mini-Hydro Department, National Electricity Board, Malaysia.

Since 1979, the National Electricity Board (NEB) of Malaysia has been actively implementing a number of small-scale hydropower projects throughout the country, with a view to serving isolated rural areas, reducing dependence on fossil fuel and boosting power to areas with inadequate supplies.

Some 22 pilot projects were initiated in 1981 and most have been implemented. A further 82 projects have been identified for implementation during the Fourth and Fifth Five-Year Plans. Of these, 16 have secured financing from the Asian Development Bank, World Bank and the Government of Norway.

The paper outlined the planning and design methodology adopted in Malaysia in the implementation of SHP schemes which included the following components:

- Feasibility Studies
- Land Matters
- Tendering Procedures
- Civil Design and Construction
- Electromechanical Equipment
- Transmission and Distribution Systems
- Project Scheduling

Through implementing the pilot projects, the National Electricity Board has gained considerable practical experience in the development of SHP schemes. This experience has been used for its project scheduling, which has now been transferred to a micro-computer, and the Board has based part of its methodology on the use of a micro-computer. The high cost of SHP schemes underlines the need to standardize methodologies and approaches, and Malaysia has come a long way in that respect. It is considered very important that the different countries exchange SHP experience at every opportunity, through publications and seminars.

### 8.12 MAURITIUS

by Louis J.G. Hebrard, Central Electricity Board, Mauritius.

Although Mauritius is a relatively small island (1,865 km<sup>2</sup>), it has substantial water resources for hydropower generation because of its varied topography and because of heavy precipitation. No fossil fuel, petroleum or gas is known to exist on Mauritius. To date, the hydroelectric installed capacity amounts to 50 MW while the thermal installed capacity (Diesel plant) is 150 MW. Bagasse, a residue from sugar cane processing, is used to heat steam boilers. During the crop season bagasse-fired power plants produce electricity. The installed capacity of these plants is 50 MW.

The paper explains the Board's use of computers in the implementation of small-scale hydropower schemes. A programme had been developed to examine the viability of small-scale schemes, on the basis of gross head and daily flow of water. This programme produces values for flow duration curves, optimum installed capacity and energy producibility. It is based on available hydrological records for 120 days and can be modified to cover available records for a whole year.

#### 8.13 MOZAMBIQUE

by Jose M.Q. Nicolau, Director, Electricidade de Mozambique.

This Country Paper was a lengthy discussion of some broad issues concerning the financing and implementation of SHP projects in developing countries. As such, it was different from other papers in that it did not touch upon the author's home country to any extent. However, the paper's intrinsic merit warrants its inclusion here in summary form, as it raises issues and problems common to most developing countries.

Development assistance is usually concentrated in areas which already possess infrastructure, markets and established systems. This is because such areas can more easily absorb assistance and can afford to pay back investments. This is particularly true of electricity corporations, who are often forced by market and commercial factors to concentrate their investments in urban areas. The question is how to encourage and promote electrification and energy development in poor rural communities, which are prevalent in countries like Mozambigue.

The two principal sources of energy in rural Mozambique are human beings (there is a very limited tradition of animal power in Mozambique) and fuelwood. This is the so-called "subsistence economy", where one of the few ways of increasing energy supply is to have large families with many children. This tends to be a vicious circle of low productivity, which is easily disrupted by climate or natural catastrophe. The author therefore argues that

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"energy planning", in its widest sense, should be given much higher priority by donors. He also argues that the appropriate authority for such energy planning is the Electricity Authority. Such authorities will have to take on much wider responsibilities than their counterparts in the developed world.

The author calls for a new approach in energy planning for rural areas, and introduces the concept of the "Dormant Power Market" as the minimum amount of power needed to raise a community above a subsistence standard of living. In meeting the demand for dormant power through small hydropower, one must remember however that small-scale hydropower is frequently of a seasonal nature. If one cannot provide storage, then the energy planner must be able to provide some alternative source of power, e.g. solar, gas, etc. However, the power source should not be imported.

The author argues strongly that once the dormant power market is awakened, the dormant creative initiative within the local community will also be stimulated, leading to progressively improved rural economic development. However, in order to initiate development, there will be need for a degree of cross-subsidization in the form of levies on commercial fuels, Government subsidies or securities issued by the Government. Finally, the author calls for the introduction of more realistic "Yearly Capital Charges", which more accurately reflect the purchasing ability of rural communities in countries like Mozambigue.

# 8.14 NEPAL

by Mahabid Prasad Shah, Small Hydel Development Board, Nepal.

Nepal's mountainous topography gives the country an enormous estimated hydropower potential of some 83 GW. It has been estimated that 27 GW of hydropower should be economically developed in Nepal. Three categories of hydropower projects i.e. large scale (up to 3,600 MW), medium scale (up to 300 MW) and small scale (up to 5 MW) are currently being developed in Nepal.

About 60 per cent of Nepal's people live in rural villages, of which 80 per cent are not accessible by road. There is a continuous drift from the mountainous rural areas to the more equable Terai plains country. In order to halt this drift, the Government is actively encouraging electrical development in rural areas. Since 1975, 10 small-scale hydropower schemes have been completed in rural areas and a further 20 are under construction. Since rural people have seen the benefits of hydropower, demand for rural electrification has been developing very rapidly and the authorities have had to draw up priority areas for development.

In Nepal some special problems exist in connection with SHP development. These are lack of transportation facilities and the high cost of transporting materials in areas with no roads, lack of skilled manpower and high operating and maintenance costs. A particular problem also noted is the lack of a coordinated, ancillary, industrial development programme for power utilization. In Nepal, local turbine manufacture has begun to take place recently, and a few turbines of up to 100 kW have been manufactured locally. This appears to be a very promising field for SHP.

Nepal is encountering numerous problems with its existing SHP schemes. Each project has to be designed and planned independently, and this takes a long time. Unit costs of generation are very high. Operation and maintenance are proving difficult because of the different types of generating equipment which have been supplied to various stations. There is a need for greater standardization both in the design of civil works and in equipment.

#### 8.15 NIGERIA

by Victor Oke, National Electric Power Authority of Nigeria.

The National Electric Power Authority of Nigeria is responsible for electricity planning in Nigeria. Total available energy in Nigeria in 1985 was estimated to be 13,762 GWh, while total available demand was 17,291 GWh, giving a deficit of 3,529 GWh. This deficit is expected to increase to 7,056 GWh by the year 1990.

The Kainji and Jebba hydroelectric schemes of 620 MW and 540 MW are already operational, and the Shiroro hydroelectric scheme is nearing completion. Several other major hydropower schemes are planned.

The National Electric Power Authority of Nigeria has been largely concerned with large-scale hydropower schemes, and small-scale schemes have been developed by other agencies, e.g. the regional electricity corporations, river basin authorities, agricultural development and water supply undertakings, etc. The National Electric Power Authority is concerned with meeting the national increase in demand for electricity of 20 per cent per annum. There is, however, a move in Nigeria towards establishing small-scale schemes for isolated rural areas because of their decreasing costs and improving technologies. In such a large country as Nigeria, small-scale hydropower can be particularly attractive in supplying remote communities. In addition, increasing drought in the north of Nigeria, along the fringes of the Sahara, is making large-scale projects like Kainji and Jebba less attractive, and this has turned policy-makers towards considering small-scale options.

The author was relatively optimistic about the future of small-scale hydropower in a large, populous country like Nigeria. It has been neglected to some extent in the recent past, but with the huge expense for large-scale schemes and the increasing fuel difficulties associated with diesel generating sets, the National Electric Power Authority is actively reconsidering the role of small-scale hydropower for the country.

## 8.16 PERU

by Victor Alcantara, Motlima Consultores S.A., Peru.

The Peruvian private sector has been instrumental in developing small-scale hydropower in the country, mainly for supplying the mining industry and related housing and community facilities. This has stimulated the public sector to develop small-scale hydropower, especially to serve remote rural areas in the Andes Mountains. About 100 SHP schemes are currently under preparation in Peru. Unit costs of such projects range from US\$ 1,000 to US\$ 3,000 per kW. In the past three years, ELECTROPERU, the State Electricity Authority, has developed 14 small-scale hydropower projects, most of which will be provided with Chinese equipment obtained through international tender.

Peru has received considerable technical and financial assistance in the planning and design of SHP from the United States Agency for International Development (USAID), which has arranged for the carrying out of 36 pre-feasibility studies. Feasibility studies for these projects have also been prepared and bid documents for contractors drawn up. Civil works contracts are limited to Peruvian Contractors, but provision of electro-mechanical equipment is open to international bidding. Similar technical assistance agreements have also been reached with the Federal Republic of Germany, the United Kingdom and Italy. Four pilot projects are being prepared under German assistance, while the British Government has agreed to assist with the development of 24 small power stations. Peru finances civil works and transmission lines, while the UK finances electro-mechanical equipment. Italy has provided assistance to build some 23 small-scale hydropower plants.

The paper concludes with a number of comments on the development of small-scale hydropower in Peru. It suggests that the standards for equipment and civil works in connection with USAID-financed projects are too high, while carrying out two separate pre-feasibility and feasibility studies seem to cause unnecessary delays. The author argues that in countries like Peru, it is essential to use as much of their own resources as possible. In addition, it is suggested that the staff working on small-scale hydropower should be experienced all-rounders, rather than narrow specialists. This will cut the cost of expensive designs considerably. Finally, the author sees a clear need for a more decentralized means of building and operating small-scale hydropower schemes in Peru.

# 8.17 PHILIPPINES

by Zenaida A. Santos, Mini-Hydro Development Office, National Electrification Administration, Philippines.

A few small-scale hydropower plants were installed in the Philippines early in the century but a concerted effort was made to develop the SHP resources from 1947 onwards. However, with the onset of an era of cheap oil, and large-scale National Grid projects, SHP schemes began to fall out of favour. The National Electrification Administration (NEA) was established in 1969 with the objective of carrying through a rural electrification programme, based on electric co-operatives. Full electrification is aimed for by 1990. NEA provides funds and technical assistance to rural electric co-operatives. At the end of 1984, 42 per cent of all rural households in the Philippines were electrified.

However, during the second oil crisis in 1978/79, oil prices rose sharply, and electricity became prohibitively expensive. This gave a considerable boost to the revival of small-scale hydropower. In 1979 a plan was therefore established to install 300 MW of capacity at about 240 power plants by 1987. Several important principles were adopted in connection with this programme. Plants were only to be established if costs were no higher than existing electricity grid rates. Plants were to be synchronized to island-wide grids, so that maximum power will minimize costs. Power plants were to be locally operated and owned by local co-operatives and the plants were to be designed and built in the Philippines. Experience with small-scale hydropower development in the Philippines has shown that the approach must be different from that used in large-scale projects. Engineering costs must be kept to a minimum and development time must also be reduced to a minimum to minimize interest cost. The National Electrification Administration is responsible at every stage for the SHP development process, either as a co-ordinating or an implementing body. The Administration obtains financing, provides management and training, carries out feasibility studies and engages technical consultants. The schemes are handed over to the local co-operatives once the project has been tested and commissioned. The co-operatives themselves are trained by NEA to be responsible for operations and maintenance of the scheme.

Because of poor economic performance of the country at large, there has been a considerable slow-down in the implementation of the Philippines small-scale hydropower programme. The overall target for the period 1985-1990 has been reduced to 155 MW, and of this 14 per cent (22 MW) will use locally-made equipment. The rest will come from Japan, China, the United Kingdom, France and Norway. To date, 11 projects have been completed under the Philippines small-scale hydropower programme, while a further two schemes were under construction in mid-1985. In addition, feasibility studies for an additional 95 schemes have already been completed. With an improved economic climate in the Philippines, it is hoped to step up construction of small-scale hydropower projects.

# 8.18 SIERRA LEONE

by Njipema N. Vandy, Project Engineer/Manager, Sierra Leone Government, Sierra Leone.

A recent assessment of Sierra Leone's hydropower potential has shown that the country has available sites capable of generating up to 3,000 MW. It is estimated that about five sites are well suited as small-scale hydropower projects.

Sierra Leone has experienced serious problems with the import of fuel for thermal generation and the National Power Authority (NPA) has had the responsibility for developing a major hydropower scheme, the Bumbuna Fall Hydroelectric Scheme, with a generating capacity of about 72 MW. This was designed to serve the capital, Freetown. However, because of the country's general economic difficulties, the Bumbuna Project has been shelved and attention has been directed to developing a series of small-scale hydropower projects. Prefeasibility studies for some four small-scale hydropower projects have been prepared by foreign consulting firms and these are awaiting further financing. A fifth project at Goma with a capacity of 8 MW is expected to be commissioned in early 1986. The project has been carried out with assistance from the People's Republic of China.

Sierra Leone has experienced considerable problems in project preparation, partly because its two divisions for thermal and hydro are within the same organisation, the National Power Authority. Thermal installations are often in disrepair, partly because the Authority was holding back investment in order to promote the new, abortive Bumbuna hydropower project in which the country has already invested millions of dollars.

In general, Sierra Leone has experienced considerable problems in attracting suitable financing for SHP projects. These have been identified, but the country's precarious economic circumstances have made it difficult to attract external financing.

# 8.19 SRI LANKA

by D. G. A. Abeygunawardana, Chief Engineer, Ceylon Electricity Board, Sri Lanka.

The use of hydroelectric power is widespread in Sri Lanka because of the country's favourable climatic and topographical conditions. The best known schemes are the Mahweli Ganga projects which have a total generating capacity of about 290 MW. Small-scale hydropower schemes were first introduced to Sri Lanka on the tea estates in 1926. About 200 very small schemes were built to serve individual plantations and had a total generating capacity of about 10 MW. However, with the introduction of a national electricity grid in Sri Lanka in 1950 virtually all the tea factories and plantations were connected to the grid and the small-scale hydropower schemes rapidly fell into disuse. Many were sold for scrap.

In 1977, a serious energy crisis hit Sri Lanka because of the rapid increase in the price of oil for thermal generation and because of drought. The cost of electricity generation therefore rose very rapidly and the Ceylon Electricity Board had to seek new alternative methods of generating electricity. Attention was again directed towards the country's small-scale hydropower projects. With assistance from the Asian Development Bank and others, Sri Lanka has decided to embark on a programme of rehabilitation and of new

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construction of small-scale hydropower schemes. Some nine projects have been identified for implementation, and refurbishing and feasibility studies have been carried out with the assistance of the Asian Development Bank. Five of the projects are under refurbishment and are due for completion by June 1985. Capital investment payback for these projects is less than six years. Each of the nine projects is under 200 kW. There seems to be considerable scope for developing SHP in Sri Lanka. There are great resources in her many rivers and SHP seems especially appropriate for the upland tea plantations. SHP schemes can be used to supply the main power with a back-up from the national grid during periods of drought.

# 8.20 TANZANIA

by Simon L. Mhaville, Tanzania Electric Supply Company (TANESCO), Tanzania.

Tanzania is fortunate in having three important indigenous sources of energy, i.e. hydroelectric power, gas and coal. Tanzania's present installed generating capacity amounts to 310 MW of which 80 per cent or 248 MW is hydroelectric. This is dominated by the large Kidatu hydroelectric scheme on the Great Ruaha River in central Tanzania. A recent identification study has shown that Tanzania has a hydroelectric power potential of about 4,000 MW.

Tanzania's national electricity grid fed from the Kidatu Station covers the coastal areas of the country and the relatively densely settled areas in the north-east. The rest of the country is covered by isolated generation and distribution facilities, each supplying power to its own limited area. The bulk of these are diesel units, but small-scale hydropower facilities exist for the towns of Mbeya and Iringa. Only 5 per cent of the total population of Tanzania has access to an electricity supply.

The country's electricity planning is based on a Tanzania Power Sector Study prepared in 1981. This Study laid down a development strategy in which dependence on isolated diesel-powered units was to be reduced (partly because of difficulties in importing fuel) by extending the National Grid, and through the systematic development of small-scale hydropower units to serve isolated or distant areas. Some 12 major hydropower sites are currently under consideration for the purpose of extending the National Grid, so that eventually virtually all thermal power facilities will be phased out to be replaced by hydropower. Given the current situation in Tanzania with the shortage of foreign exchange and the difficulties in importing diesel fuel for thermal stations, small-scale hydropower is a particularly attractive option for serving remote or distant communities --- especially where the topography and hydrology are suitable. A recent study has identified some 80 potential small-scale hydropower schemes throughout the country for which feasibility studies are already being carried out for nine sites. Tanzania is concerned about the high initial costs and the time required to implement SHP stations in comparison with diesel stations. However, the relatively low operating costs of SHP are an attractive proposition. One thing is certain, however, and that is that Tanzania can and will base its power supplies on indigenous fuel resources, and this will most certainly include an active development of SHP.

## 8.21 THAILAND

by Suthep Liumsirijarern, Resident Engineer, National Energy Administration, Thailand.

The use of water power has always had a tradition in Thailand with the use of bamboo waterwheels for lifting irrigation water. The first small hydropower scheme was introduced to Thailand in 1930, but SHP was introduced only very gradually into the country. Between 1961 and 1981 only three new small-scale hydropower schemes were commissioned.

The oil crisis of the 1970s gave a new impetus for the development of SHP in Thailand. SHP was given a new role for power development in Thailand's Fifth Five-Year National Economic and Social Development Plan (1981-86). The total hydropower potential in Thailand has been estimated at 9,300 MW and the combined potential capacity of small-scale schemes is estimated as 1,000 Mw. It is planned to implement some 100 small-scale hydropower projects (of under 6 MW) in Thailand under the Fifth Five-Year Plan. The National Energy Administration of Thailand has prepared plans and feasibility assessments for these projects and assembles data on hydrology, geology, socio-economy, environment and power market for each scheme. Comparison is also made with thermal alternatives. Each scheme study takes about two years to complete. However, for the smaller "micro"-hydropower projects of under 200 kW, a different approach is needed in order to minimize investment costs per kilowatt installed. Much greater participation from the local Community in construction and operation is necessary to reduce such investment costs. A somewhat smaller approach is also adopted for

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implementation. For larger small-scale hydropower schemes i.e. above 200 kW, contractors are used for civil works and overseas contractors are often responsible for supervision of electrical and mechanical work. For the small schemes of under 200 kW, a local village cooperative is formed to construct the project with assistance from the National Energy Administration.

At the moment overseas contractors are still employed in supplying electrical and mechanical equipment through international bidding. However, Thailand's capacity in these fields is developing fast, and it will be possible to use local contractors for this in the not-too-distant future.

# 8.22 UGANDA

by Martin L. Okiror, Uganda Electricity Board, Uganda.

It has been estimated that as much as 3,000 MW of hydropower can be derived from the River Nile as it flows from Lake Victoria to Lake Albert. In the recent past Uganda has tended to depend on development of large-scale hydropower and extensions of the National Grid from the existing Owen Fall Hydropower scheme at Jinja, rather than develop any small-scale hydropower capacity.

A number of small-scale hydropower potentials have been identified in Uganda although most are awaiting suitable financing. Only one small-scale hydropower scheme actually operated in Uganda, at Mobuku Power Station, and this was built in conjunction with the deveopment of the Kilembe Copper Mines in Western Uganda. The scheme has a generating capacity of 6,200 kW. The Uganda Electricity Board is in the process of connecting this station to the National Grid. A number of other promising potential projects have been identified, several of which could serve both urban and mining markets in Western Uganda. The planning of several of these schemes, including the Karuma Falls project, has been taken to an advanced level and in several cases little has to be done before the project can be financed.

The Uganda Electricity Board has also identified numerous potential SHP sites on the streams running from Mount Elgon in the east of the country. All in all, there is no shortage of potential sites and projects, but with the difficulties of obtaining finance and the continued dominance of large-scale hydropower projects in feeding the National Grid, the future for the development of SHP in Uganda is still somewhat uncertain.

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Annex 1

PROGRAMME (10-18 June 1985)

A. Monday, 10 June

# 1. Morning

Official opening of the Seminar by Mrs. R. BRUSLETTEN, Minister for Development Co-operation, Norway

Introductory remarks by Mr. J. STORAAS, Ministry for Development Co-operation, Norway

"Norwegian Energy Policy with Special Reference to Small-Scale Hydropower" by Mr. A. VINJAR, Norwegian Water Resources and Energy Administration

Remarks by Mr. N. BEREDJICK, United Nations, Mr. B. HARLAND, UNDP and Mr. W. TANAKA, UNIDO

"The Role of Small-Scale Hydropower in Energy Planning and Supply, Globally Seen" (Paper prepared by Mr. K. GOLDSMITH, and presented by Mr. N. BEREDJICK)

#### 2. Afternoon

#### PROJECT PLANNING

Session Chairman: Mr. J. NICOLAU

"Methodologies for Planning and Feasibility Assessment" by Mr. W. BEHRENS, UNIDO

"Small-Scale hydropower development - The project planning cycle" by Mr. J. LINDEMARK, Norway

Discussion

Country Papers

Summing up session

1. Morning

Session Chairman: Mr. N. HARTOYO

"Site identification and data collection for SHP" by Mr. T. Aamodt, Norway

Discussion

"Identifying markets for small hydropower" by Mr. D.A. ZOELLNER, NRECA, USA

Discussion

2. Afternoon

Session Chairman: Mr. O. QUIROGA

"Methodologies for establishing development criteria and costs" by Mr. D.K. LYSNE, Norway

Discussion

"The evaluation of small-scale hydroelectric projects for international financing - The case of the Inter-American Development Bank" by Mr. G. CALDERON, IADB

Discussion

Country Papers

Summing up

# C. Wednesday, 12 June

Visit to manufacturer of turbines for SHP schemes and site visits

D. Thursday, 13 June

# 2. Morning

# DECISION-MANKING

Session Chairman: Mr. S.L. MHAVILLE,

"Review of the pre-investment cycle and establishment of development criteria" by Mr. E. MALQUORI, ENEL, Italy

"Selection of technical solutions for the building of SHP stations" by Mr. K. SORLI, Norway

Discussion

"Financing, tendering and contracting considerations" by Mr. P. WIEBE, Canada

Discussion

## 2. Afternoon

## IMPLEMENTATION

Session Chairman: Mr. L.J.G. HEBRARD

"The construction cycle and scope for local participation" by Mr. A.J. BROMLEY, UNIDO

Discussion

Country papers

Summing up

Site visit to Heiernfoss Hydro Power Plant

# E. Friday, 14 June

# 1. Morning

Session Chairman: Mr. B.M. SINGH

"Considerations associated with local manufacture of electro-mechanical equipment" by Mr. W. TANAKA, UNIDO

Discussion

## OPERATION AND MAINTENANCE

Session Chairman: Mr. A.N. LAWSON

"Operation of SHP schemes and their integration into utility systems" prepared by Mr. N. JUELL, Norway and delivered by Mr. N. FOSSEN

Discussion

2. Afternoon

"Training and maintenance aspects in connection with SHP development" by Mr. O. HOFTUN, Norway

Discussion

Summing up of the Seminar by Mr. A. VINJAR

F. Study Tour: Sunday, 16 June

1. Morning

Oslo - Bergen

2. Afternoon

Visit Kaldestad power plant

G. Study Tour : Monday, 17 June

1. Morning

Visit Sima power plant

2. Afternoon

Stop at Voringsfossen and Sysendammen

Visit Ustekveikja power plant

# 1. Morning

Stop at Djupdal power plant

Visit Holseter power plant

# 2. Afternoon

Visit Vestfossen power plant

Return to Oslo



MAP NO. 3380 UNITED NATIONS JUNE 1986

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