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SMALL HYDROPOWER AND RELATED ASPECTS TO INDUSTRIALIZATION*

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ABSTRACT

The purpose of the paper is to introduce UNIDO's work and experience in the field of SHP with specific reference to the industrialization process in developing countries. In particular, the author of this paper (J. Fürkus) considers the relationship between energy and industrialization, highlighting the SHP component, its potential for rural development, agro and small scale industry. The paper illustrates UNIDO activities in the field of SHP, i.e. the scope, areas, project related activities and relevant experience. Engineering aspects of SHP projects are being discussed such as the state-of-the-art, local design and manufacture, standardization, technical requirements for mechanical, electrical and civil engineering components, repair and maintenance. Finally, it refers to the transfer/adaptation of technology and collaboration with developing countries, explaining among others, requirements, mechanisms and procedures for technical assistance and presents appropriate conclusions. On the basis of this paper a presentation was made by the author at the International Conference Small Hydro '88 in Toronto, Canada, 1988.

CONTENTS

1. Introduction:

The introduction and application of SHP in developing countries is an integral part of UNIDO's energy related technical assistance activities and contributes to the process of industrialization.

The importance of energy and energy-related technologies to the industrial development of developing countries emerged in the context of the Lima Declaration and Plan of Action on Industrial Development and Co-operation resulting from the Second General Conference of the United Nations Industrial Development Organization held in 1975.

The Third General Conference of UNIDO, held at New Delhi in 1980, referred specifically to energy in the process of industrialization. It stressed that the development of new and renewable sources was required in addition to the continued utilization of conventional sources of energy. Attention was also called to the need to rationalize the consumption of energy at the global level, particularly by developed countries. The New Delhi Declaration and Plan of Action on Industrialization of Developing Countries and International Co-operation for their industrial development contains a number of recommendations specifically related to energy.

As a follow-up to the UN Conference on NRSE in Nairobi in 1981 and UNIDO's 4th General Conference in Vienna (1984), growing attention has been given to the development of technical co-operation projects in hydro-power, biomass, solar and wind including the support for regional co-operation and exchange of information particularly among developing countries and the promotion of local design and manufacture of equipment. However, compared with the requirements and possible application of SHP technologies for the exploitation of the world's hydro-electric power capacity the utilization of SHP is not predominent, specifically in developing countries. This shows the great potential and need for joint efforts to accelerate the transfer of know-how and to promote the development of technological capabilities and human resources in the field of SHP in line with local priorities using the system of international co-operation.

2. Energy, SHP and Industrialization:

2.1 Considerations on Energy/SHP Resources and Requirements and Interrelation with Industry

The major purpose of UNIDO is to promote and accelerate the industrialization of developing countries. In support of that role, UNIDO performs its mandate as the 16th specialized agency of the United Nations System on the basis of its constitution which came into force in June 1985 and through the realization of appropriate programmes and technical assistance activities, which are due to facilitate the fulfilment of its functions.

Energy is of crucial importance to the industrialization process and the efficiency, scope and technological level of industrial development with its economic, technical consequences and social implications depends to a large extent on the effective introduction and application of related technologies.

Despite of the slow-down of the economic growth, if compared with previous years, and the efforts towards a more rational and sparing use of energy, it is assumed that the demand for energy during the forthcoming decades will continue to grow on a worldwide basis although differing among countries according to specific conditions and policies. The share of developing countries in the world's energy consumption needs was nearly 15 % in 1980 and is expected to grow up to 27 % in the year 2000 and 40 % in 2020 according to the World Energy Conference held in 1980. Following these figures and assessments of the 13th Congress of the World Energy Conference in 1986 it can be stated that the developing countries will have an above-proportional growth rate of their demand for energy in future.

. In the light of the increasing dimension of energy consumption and the limitation and unequal distribution of the most effective conventional energy resources it is necessary to diversify energy sources mobilizing alternative sources on a substantive scale.

Projections on the future share of renewable energy sources in the total balance of energy supply vary from each other. The share, however, is growing and shall reach 10 - 15 % in the year 2000 following the predictions of the UN Conference on NRSE (Nairobi, 1981).

Among NRSE, above all hydro-power, biomass and solar energy are likely to make significant contributions to the overall demand for energy from the industrial sector of developing countries on short and medium terms.

The estimated world's potential hydro-electric power capacity is about 2.2×10^6 MW. Approximately 60 % of this potential exists in the less developed countries of Latin America, Africa, Asia and the Pacific Islands. However, compared with the requirements and potential resources the utilization of hydro-power, especially that portion below 5 MW capacity is largely under-developed. Only about 16 % of the total technically usable hydro potential in Asia and about 13 % of the corresponding rate of utilization in South America have so far been harnessed. For Africa, the corresponding proportion is only 4 % compared to 94 % in Europe. Mini-hydro projects (under 1 MW) might comprise 5 - 10 % of the world's total hydro resources.

For effective and sustained industrial develpoment, energy production and utilization must be planned with other factors, such as technology, human resources, raw materials and finance.

The interdependence of energy and the industrial sector is of major concern for governments of developing countries in formulating both energy and industrial policies. Industry is a major market for energy, and developments in industry closely affect the energy sector, just as developments in the energy sector affect industry. The size and structure of the industrial sector determines the amount and type or form of energy needed. Similarly, the availability and cost of energy supplies has a major influence on industrial development. The Lima target, namely that developing countries should achieve a minimum of 25 % of world industrial output by the year 2000, requires for its achievement correspondingly massive inputs of energy.

As an indication of the energy implications of industrialization in the near future, estimates made by UNIDO of the energy needed to achieve the Lima target show that the energy requirements of the developing countries would have to increase from 1,600 mln tonnes oil equivalent (mtoe) in 1975 to some 6,500 mtoe by the year 2000.

The energy reserves and resources necessary for this increase are available if all sources of energy, and not only oil, are considered. In fact, it was proposed at the United Nations Conference in New and Renewable Sources of Energy held at Nairobi that up to 50 % of the increased energy requirements of the developing countries be covered by new and renewable sources of energy. Achieving this calls for a major effort covering all forms of energy, conventional and otherwise new and renewable, and requires, in turn, both financial and technological support at all levels and co-operation in all forms, including trade.

Industry is a major consumer of commercial energy in the developing countries. It has been estimated that the average for all developing countries is around 35 % but there is, of course, wide variation between countries. The manufacturing sector is the major user of industrial energy, accounting for between 20 and 45 % of total energy consumption. Currently the developing countries have to import some 60 % of their commercial energy. This has an obvious and serious effect on their balance of payments.

In view of the above, small-scale hydro-power plants in the range from 10 KW to more than 5000 KW can increasingly become an economically viable and reliable source of energy specifically for rural and isolated areas and there are quite a lot of countries, including those from the third world where the availability of SHP and its application has proved to be an effective means to promote industrialization, rural electrification and mechanization, economic and social development.

A survey of SHP capacities in some developing countries is given in Table 1 overleaf.

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

Country name	Year of Refer.	Exploitable Capability* (GWh)	Capacity Operational (MW)	Planned (MW)
Argentina	1984	38	7	11
Burundi	1984	U	3	0.86
China	1984	210,000	9,060	71.300**
Cyprus	1982	23,500	0,65	0.9
Indonesia	1984	U	15.64	U
Jamaica	1984	U	C	2.5
Jordan	1984	14	U	U
Korea (Republic of)	1984	U	1.85	17.85
Malaysia Sarawak	1984	U	3.22	27.11
Mexico	1984	U	69.4	U
Nepal	1983	U	U	1.27
Philippines	1984	U	1.2	U
Portugal	1984	15,000	-	6,000
Sri Lanka	1984	263	1	3.5
Taiwan	1984	U	3.3	10.6
Thailand	1984	U	2,846	20.893
Venezuela	1984	U	23.31	0.415
Zambia	1984	8.76	0.75	0

Source: World Energy Conference, Survey of Energy Resources 1986.

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

Note **: Exploitable capacity

U: Denotes unavailability of information

2.2 SHP in Rural Areas

Developing countries are faced with growing problems of energy deficiency, particularly commercial energy resources for rural development accompanied by a depletion of non-commercial/traditional sources and negative effects on the environment (deforestation, soil erosion) and the country's social and economic status.

This situation calls for an integrated and long-sighted approach to the use of all promising forms of energy specifically NRSE and SHP as a major component with a great potential for agriculture, rural and small-scale industry.

SHP can be used for the production of electrical and mechanical energy required for community electricity supply, water pumping for domestic use, livestock and irrigation, for crop processing, threshing, grinding, milling, etc. and agro-industry. SHP units are very well suited to replace diesel generators, to complement existing grid supply or to provide electricity for remote decentralized installations.

The relatively large capital requirements at the initial stage and the low load factor in rural areas (which may vary from 0.10 to 0.25 compared to perhaps 0.50 in urban areas of developing countries) are of crucial importance to the economic viability of SHP schemes since a high utilization factor can keep the unit costs down and vice versa. Table 2 (Ref. No. 25) is reflecting this accordingly.

Table 2: Total electricity generating costs of small hydroelectric plants

Load factor (%)	Discount rate (%)	Total cost ($/kWh)		
		$ 1,000/kW	$ 2,000/kW	$ 3,000 kW
40	5	0.04	0.07	0.11
	10	0.05	0.09	0.14
	15	0.06	0.11	0.17
30	5	0.05	0.10	0.15
	10	0.06	0.12	0.18
	15	0.08	0.15	0.23
20	5	0.07	0.15	0.22
	10	0.09	0.18	0.27
	15	0.11	0.22	0.34

For comparison a 1.000 kW diesel generator with $ 700/kW capital cost, 15 years life time, 45 % load factor and $ 0.5 fuel cost per litre would have generating cost of around $ 0.14/kW at 10 % discount rate. The need to provide electricity from SHP at reasonable costs must not be underestimated. Rural electrification, however, remains a prerequisite for development and SHP should play a growing role. Energy planning, SHP and potential other renewable sources of energy like biogas and solar must, therefore, be integrated into rural development plans bearing in mind economic, technological and financial consequences, as well as social implications.

3. Technical Assistance Activities:

3.1 Energy/NRSE related TA activities and SHP

Statistical data on UNIDO's disbursements on energy, NRSE, SHP are given in Annex 1 and 2. UNIDO delivers yearly about US$ 100 mln of technical assistance. 10 % of this assistance is related to energy. In the year 1980 it was only 5 % (Annex 3). The increase of the NRSE share is even more impressive as reflected in Annex 5. In the year 1980 the NRSE share amounted 0.5 % of UNIDO's technical assistance. By the end of 1987 an almost constant NRSE share of 3 % can be recorded. Annex 5 illustrates this development comparing NRSE with the total energy disbursement in UNIDO's TA programme.

A breakdown of UNIDO's NRSE disbursements by region and source is given in Annex 6 covering the period 1980 - 1987.

The development of UNIDO's technical co-operation programme on SHP since 1980 is shown in Annex 7 with a total of 27 completed or ongoing projects with a total expenditure of around US$ 4,042,000 between 1980 and 1987. Increasing attention is paid to the least developed and the African countries. Priority areas of the SHP programme are:

- Planning and integration of small hydropower into rural industrial development;
- Pre-feasibility and feasibility studies;
- Designing of small hydropower plants, including civil engineering;
- Technological development, technology unpackaging and standardization of components and systems for local manufacturing;
- Support of regional co-operation and exchange of technical information;
- Investment promotion;
- Training, organization of workshops and seminars, fellowships, studytours and on-the-job training.

At an earlier stage the main scope of UNIDO's assistance was aimed at encouraging developing countries in the application and local manufacture of small hydropower for rural industrial development by creating regional networks for co-operation in research and devleopment and organizing workshops, training courses, seminars and study tours.

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

Technical co-operation in SHP must, indeed, be focussed on strengthening the developing countries own technological capabilities and resources. Reviewing, however, technical assistance activities from the contents point of view and with regard to the objectives to be achieved even more official requests for technical assistance in SHP development and more projects with real implications to the upgrading of the quality of life and economic well-being of people in developing countries and concerned communities seem to be needed. Conferences like this can contribute to the process of creating a greater awareness of the need and possibility for more practical projects or ideas and concepts which may lead to viable project proposals.

3.2 Selected SHP Projects:

3.2.1 The Asia-Pacific Regional Network for Small Hydropower (RN-SHP) and the Regional Centre for SHP at Hangzhou (HRC)

UNIDO has been actively involved in project activities related to the establishment of the "Regional Research, Development and Training Centre for Mini-Small Hydro Power Generation" in Hangzhou, China, to function as the focal point of a network of national Mini-Hydro Power generation organizations/institutions determined by the individual member countries of the region. This project (DP/RAS/80/033) covers a total UNDP component of approximately US$ 700,000 with roughly US$ 95,000 for expertise, US$ 190,000 for training and US$ 305,000 for equipment and is being carried out in conjunction with two other projects subcontracted to UNIDO by ESCAP/REDP* namely DU/RAS/84/001 and DU/RAS/86/136 totalizing US$ 370,000 and DP/CPR/81/004 with a UNDP input of US$ 352,000 respectively. The total sum of these projects is about 1.5 mln US dollars, in which approximately 31% was used for equipment, 29% for training/workshops and the remainder for other activities (expertise, etc.).

The Chinese Government has also paid great importance and has given substantial support to the establishment of the Regional Centre for SHP at Hangzhou. The total amount of funds allocated from the Ministry of Water Resources and Electric Power to the HRC was equivalent to US$ 2.4 mln for capital investments of the buildings and salaries and overheads.

A 14 floor building of the HRC with 6000 m^2 is quite well equipped including video-audio equipment, language laboratory, simultaneous interpretation systems and other equipment and can be used for various activities in the Regional Network Projects particularly in the fields of training, information and consultancy.

The RN-SHP work programme for the period 1987-1991 which was prepared during the Second Technical Advisory Group (TAG) Meeting held in October 1986 in Penang, Malaysia, includes, for instance, five training workshops, five research and development (R + D) projects, four expert group meetings to assess the R + D projects, two consultation missions, four missions of the TAG and the RN-SHP newsletter.

R + D projects will cover areas of socio-economic impact studies of SHP, planning and design guidelines, standardization of civil and electro-mechanical equipment, local manufacturing of SHP equipment and unmanned and remote operation of SHP stations and grid systems.

There will be training workshops on socio-economic aspects of SHP development, construction management of SHP development, and watershed management and environmental impact assessments.

In addition to this work programme, the Network plans to undertake other activities. One of the projects of the Network is to compile a roster of SHP experts, research organizations and equipment manufacturers. Research and development and training activities can be conducted by countries which meet the required facilities.

The RN-SHP also plans to establish linkages with other networks and organizations that are engaged in activities related to SHP.

* Regional Energy Development Programme

In summary, both the facilities and experience gained at the HRC has been and will be further increased to a higher level so that the Regional Centre for SHP can fulfil its function as a Centre of excellence for training, co-operative research and development, information and advisory services in SHP.

3.2.2 Hoha Mini Hydropower Project in Africa

The Hoha Mini Hydropower project SI/ETH/85/803 refers to the development of a MHP plant in Ethiopia. The project site is located about 750 km to the southwest of Addis Ababa. The plant shall provide the regional centre and border town of Asosa with energy produced by hydropower. Due to its remote location the Asosa region is not integrated in the national electrical grid. The MHP plant is basically a run-off-the-river scheme, located on the right bank of Hoha river, near the waterfalls, consisting of a diversion weir with intake, about 2.4 km of open head race canal, forebay, 265 m of penstock route and a powerhouse for two units with an installed capacity totalling 650 kW. The project includes 6.5 km of new access roads, housing for staff and about 10 km of transmission line. Hydrological data indicate that a flow of 0.3 m^3/s is guaranteed 90 % of the time to be translated into electricity under a head of 135 m. The main characteristics of the Hoha Hydropower Plant are reflected in Annex 8.

The objectives of the project are:

- to encourage rural industrialization using local manpower and manufacturing resources through the development of mini-hydropower;
- to analyse available studies on mini-hydropower generation with the aim to identify ways in which they can be implemented at low cost, utilizing local manufacturing capacity to the fullest possible extent;
- to prepare engineering plans for the project including the rehabilitation of existing turbine generator set from a shut-down MHG plant;
- to identify small-scale rural industries that could utilize the energy made available by the project.

It was further considered to base the power plant technology as far as possible on the level of technology prevailing in local industries and to stimulate the local manufacturing sector to improve their technology and participate in the production/adaptation/rehabilitation of MHP equipment.

After installation of the first set with a capacity of 300 kW which is scheduled to be commissioned in 1988 in Phase 1, a second unit of 350 kW is required in 1989 in Phase 2, in order to cope with the forecast increase in demand. In Phase 3, a dam may be added to increase availability of the plant. The economies expected from the dam may also benefit from irrigation, which could be implemented downstream of the power plant, making use of the regulated flow, especially during the dry season.

The technical work during the design phase was conducted as teamwork involving in all disciplines local experts and their counterparts in a way, that a full technology transfer would occur.

The training on-the-job aspect was observed and use was made of the planning capabilities inherent in the team. Also, during conception of the structures, efforts were made to utilize local manufacturing capacity to the fullest possible extent.

Thus, the hydro-mechanical equipment was provided for local manufacture, including part of the penstock. The civil structures will be executed in masonry from natural stone available in the area. Reinforced concrete will only be used where unavoidable. The whole head-race canal is foreseen to be built with local manpower and manual labour. All repair and erection work for the various components of the project will be executed using local skill, including the rehabilitation of the existing turbine-generator and its accessories.

The results of the economic analysis have shown that the energy to be expected from the mini-hydropower plant can easily be absorbed in Asosa and that hydropower would be less expensive than diesel power which in addition to its high price is import-dependant. It can also be deduced from the economic analysis that all three project phases should be implemented in the shortest possible time.

However, the project budget available at the time of review work in 1986 did not allow to cover all engineering services required for the implementation of the project specifically with regard to detailed engineering related to the construction work and the irrigation aspect including the dam design and the layout of the irrigation scheme so that further assistance is needed to complete the project as scheduled.

With respect to the development of local manufacturing capacities it was, among other things, recommended to:

- Establish a range of cross-flow turbines adequate to the most frequent applications in the country for local manufacture and start a turbine production with small and simple units using existing experience and facilities;
- Manufacture locally hydro-mechanical components like gates, trashrack, part of the penstock and develop a suitable type of governor which can be produced in series involving, if necessary, an experienced manufacturer abroad during the initial production phase;
- Extend gradually the range of turbines into bigger size and higher heads in parallel with the increase of production capabilities;
- Start at a later stage, probably after the production of electric motors has been taken up in the country the manufacture of small generators for the combination with the cross-flow turbines locally produced.

It was estimated that a local manufacturing capacity for a limited range of cross-flow turbine units could be set up in less than five years on the basis of coordinated efforts. Cross-flow turbines were recommended because they are quite suitable for local production as generally known since the rotor and casing can be made from sheet steel and the requirements for welding, turning, grinding, etc. are moderate whereas Kaplan, Francis and Pelton turbines require relatively highly developed casting, forging and welding techniques.

3.2.3 Small-scale hydropower in Island Countries

As an example, reference is made to hydropower projects in the Solomon Islands. Studies have shown that this country has a great potential for the development of small, micro and mini hydropower capacities. The annual rainfall in most land areas is 3,000 - 5,000 mm distributed throughout the area. The present installed power capacity in the country is only about 8,000 kW, almost all of which is generated by diesel plants and at present only 11% of the total popultation have access to electricity.

In 1986 under the project SI/SOI/85/802 assistance was given in formulating a development programme on MHP projects. A technical report was prepared recommending, among others, four projects for immediate development. Three of them are in the range of 100 kW and one of 6 MW capacity. It was also proposed that the three 100 kW plants be developed as pilot mini-hydro schemes with top priority for one of them, thus providing an opportunity for the Solomon Islanders to gain experience and training in engineering design, construction and operation of MHG plants. The report also advised on future work to get the projects implemented.

However, a micro-hydro-electric pilot plant was installed in 1983 under the project US/SOI/83/076 sponsored by the Australian Government through the special purpose contribution to UNIDF and follow-up activities were arranged in 1985/86,mainly in repair, maintenance and training.

The purpose of the project was to initiate the construction of a micro-hydro-electric power generating plant in the village of Iriri on the island of Kolombangara in the province of the Western Solomons and to implement it as a pilot project for future applications throughout the Solomon Islands Republic, thus encouraging rural industrialization using inherent skills and local resources. In the course of project implementation local people had to be trained in planning, constructing, installing, operating and maintaining such power generation systems to that the hydro scheme can be used in line with the needs of the Iriri community.

The main components of the system consisted of:

- the village reticulation, i.e. housing wiring for lighting, and selected power points in community structures for cottage and light industry;
- the electrical transmission of electricity from turbine to the village by a 1.3 km underground double-insulated cable;
- the civil hydraulic construction (dam, penstock etc.). The pipeline of approximately 1 km for conveying the water to the turbine was constructed of high-grade UPVC, treated for an indefinite lifetime in tropical environments and supported by a timber structure from the damsite;
- the turbo-generator unit consisting of a Pelton wheel turbine attached by a belt-drive to a 12 kVA Dunlite self-excited brushless single-phase alternator.

The use of brushless alternator was considered mandatory to meet the low-maintenance requirements set by the design criteria.

The Pelton wheel design for the turbine was selected with the long-term objective of local manufacture.

Although fully up-to-date figures on Iriri's returns from its electrification are not available, several economically measurable sources of returns related to wood-processing, craft production, guest accommodation and fuel replacement battery charging, indicate the scheme's numerous benefits. Following the figures of the final report the annual economic return attributable to the hydro scheme is at least $ 7,500.

The scheme would, if repeated, justify itself on a standard bank-loan basis, in that yearly income exceeds loan repayments from the outset. The so-called payback period, if defined as the time taken for income to exceed capital costs, should be less than four years.

The project has proved to be a justified initiative in the field of micro hydropower development. It has indicated the right approach to design of the Iriri scheme, verified its pilot character and has shown its demonstrative effect. However, subsequent decisions for a more wide-spread implementation require appropriate policies and mechanisms of interested governments and should take into account basic lessons from the Iriri pilot project and conclusions as outlined in the Final Report.

4. Engineering Aspects of SHP Projects

4.1 Advantages and limitations of SHP

As a matter of fact, on a world-wide basis, both the need and the market exist for large numbers of mini and even micro hydropower plants. Hydropower is, however, site specific and beside all endeavours towards standardization each type of project, depending on the power range requires a different approach, its own design philosophy and different standards for construction. Plants with a capacity of more than 1 MW require, as a rule, full studies, expert design and experienced contractors, whereas micro-hydro schemes mostly follow simplified construction techniques with a maximum of local input. Small mini-hydro plants in the range of 100 to 1,000 kW are often a compromise between both extremes with a tendency towards the simplified design and construction techniques of micro-hydro.

In any case a realistic approach is required to make the best use of the specific advantages of SHP plants. Today SHP is generally based on a well developed technology adaptable to local conditions. MHG plants can quickly be built, compared to large hydropower installations, have low operating costs, long service life, if properly designed, manufactured and constructed, have little adverse environmental impact and require cheap and simple maintenance. SHP opens up increasing possibilities for the use of indigenous materials, equipment, local skill and manpower.

However, although well developed there is still room to improve the state of the art of small-scale hydro technology. Mechanical and electrical equipment must often be individually designed to overcome the unique problems of each site and to optimize the available potential.

Turbine technology is mature. Many of the newly designed turbines have seldom substantial advantages over traditional turbines.

Nevertheless, SHP is still a challenge to its designers. It offers a wide range of options, innovative ideas and new concepts for systems of low costs and high efficiency by a combination of functions from different designs.

As far as standardization is concerned it is generally recognized that standard turbines, i.e. the production of a range of units of identical design is specifically applicable to mini and micro turbines where cost is important and where the efficiency might be considered of lower priority.

Electrical systems should also be standardized wherever possible to ease the load on maintenance, to minimize spares holdings and to encourage local manufacture. Because even a large variety in the ratings of electrical equipment will not lead to excessive costs or deterioration of efficiency, it is not so difficult to design a limited range of standard control and protection systems, switchgear and transformers which are suitable for outputs from a few hundred kilowatts or even less and up to several megawatts.

SHP has also disadvantages like (a) high unit investment costs per installed kW which varies considerably (US $ 1,000 - 5,000 per kW) depending on head-, site -, and other local conditions, (b) high study costs in relation to overall investments and (c) the prospects for the continued operation of the plants depending, for example, on hydraulic resources, meteorological and seasonal conditions, etc.

Several attempts have been made to reduce these limitations. New ideas are mainly aimed at changing the traditional concepts of preparing and implementing SHP plants avoiding, if possible, or minimizing the necessity for detailed analyses and optimization procedures to ensure availability of power at the earliest possible date. Economic analysis, for instance, can sometimes be limited to direct comparisons with diesel generation. Other approaches are oriented towards the application of standardized equipment, the utilization of pre-fabricated and/or pre-assembled units and components, the development and introduction of low-cost designs and simple technology to ensure a maximum local participation in equipment production, plant construction, reliable operation and an easy maintenance and repair.

In order to follow simplified approaches it is essential for the design of the installation to have sufficient and reliable input data on the water flow, topography, technical specificiation etc. since site, loading and operating conditions determine the engineering design and application of MHG plants.

4.2 Local manufacture and technical requirements

Considerable savings are possible if locally fabricated equipment is used. However, this requires the availability of local know-how and appropriate production capacities, adequate workshops or at least multi purpose production units which may also be considered for manufacturing components or sets of hydropower equipment.

Local manufacturing capabilities should be developed gradually and in line with national programmes and priorities by mobilising indigenous resources and intensifying international assistance including technical co-operation among developing countries.

Problems of local manufacturing should in no way be underestimated. A potential market, viable SHP sites, engineering plans, machinery and funds are necessary but not sufficient prerequisites for the production of SHP equipment. In order to produce and install SHP plants up to the international standard very well-trained engineers and technicians with practical experience in SHP technology as well as skilled personnel at the shop level, such as machine operators, welders, mechanics, fitters, plumbers, electricians and carpenters are required. In addition, a gradual involvement of local organizations and companies in production processes of SHP is necessary and more pilot plants must be materialized to enable developing countries to get their own experience and to develop their local know-how in the design, manufacture, operation, repair and maintenance of complete SHP sets or components and to establish their national engineering resources and consulting services.

The practice has already shown that in countries with large SHP potential engineering capabilities can successfully be developed by utilizing local resources. On the whole, however, the establishment of local design and manufacturing capacities is still rather slow.

The conventional approach of utilizing deliveries and services from industrialized countries which includes, for instance turn-key delivery of equipment remains probably dominating in countries with limited potential of viable SHP sites. It may also be applied to countries which enter the SHP scene, so to say as an intermediate stage to bridge the gap until domestic manufacturing capability exists. This would enable practical training of national experts in SHP development including planning, design and construction work, operation, repair and maintenance of SHP plants thus encouraging the involvement of indigenous resources in follow-up projects.

As far as technical requirements are concerned, machinery, i.e. machine tools and instruments for the local production of SHP component parts, has to be specified in line with the type of SHP equipment needed. As a general approximation well-equipped workshop facilities are required consisting of a combination of different types of machines including lathes, drilling, cutting bending, grinding, milling, shaping machines and special equipment for welding winding, casting, forging, balancing, lifting, testing and measuring. Furthermore, appropriate materials and semi-manufactured goods are needed like sheet metal, steel bars of various profiles, welding rods, non-ferrous metals, insulating materials and standard smaller component parts for a mechanical or electromechanical workshop.

The capacity of SHP plants are mainly determined by the stream flow and head. Unit costs rise rapidly as power ratings decrease and plants with low heads are more costly than those with high heads (in the proportion of 3:1 for heads of 5 and 200 respectively). Real costs of SHP plants have to be analysed in each individual case. However, referring to figures from a well established manufacturer of small scale hydraulic turbines and related equipment the following breakdown of cost may be given to characterize the overall cost factors for SHP plants:

- Production and installation of metal component parts (including the pipeline and related metal parts) : 10 - 20 %.
  (This part of the work can be executed by a company experienced in the production of metal hardware, e.g. steel structure, pipework, if supported by a company experienced in the construction of SHP).

- Production and installation of turbine: 20 - 30%.
  (Experience in the construction of SHP is necessary, or at least a close co-operation in a process of gradual transfer of know-how from a company experienced in SHP plant construction).

- Production and installation of electrical parts: 15 - 30%. (This part of the work can be executed by a company experienced in the production of medium-sized electric rotors and switch gears, if supported - at least for some time - by a company experienced in the installation of SHP plants).

- Local civil works: 30 - 60 %. (This part of the work can be executed by a local company experienced in the setting up of SHP stations).

From the same source it is indicated that the overall cost of maintenance of an SHP plant during its life-span of about 30 - 40 years and even longer if properly maintained, amounts to approximately 10 to 20 per cent of the construction and installation cost of the respective SHP plant.

Repair and maintenance, spare parts supply and/or production of spare parts should be considered as an integral part of each SHP project. Effective repair and maintenance services can be considered as a means of the entry into the manufacturing sector and to build up local skills. Major equipment repairs require specialized workshops and competent maintenance personnel. Preventive maintenance, minor emergency and general equipment repairs or general repairs to the civil engineering structures may be handled by qualified operators with the support of the community or utility.

There are general recommendations or maintenance procedures from the manufacturers side on the cycle of necessary repair and maintenance work. These recommendations are related to the individual components of SHP plants including civil constructions and electromechanical equipment and should be followed thoroughly.

5. Technology Transfer and Co-operation with Developing Countries

5.1 Transfer of Technology and Procedures for Technical Assistance:

UNIDO in its endeavours to assist developing countries in SHP application and to facilitate the flow of know-how promotes the transfer of technology through:

- studies and publications on SHP technologies;
- the exchange and publications on SHP technologies;
- the exchange of experience using expert group meetings, study tours, regional networks;
- training in various aspects of SHP;
- advisory services by consultants, experts, etc;
- co-operative programmes of applied R + D of SHP between countries regions;
- the establishment of prototypes and demonstration units;

One of the most effective ways to acquire up-to-date technologies is the practical implementation of SHP schemes and the development of appropriate design, production and training capacities stimulating local participation and inherent skills.

The scope of the local content of SHP projects and the respective technology package to be transferred depend on the availability of indigenous engineering and consultancy capabilities.

SHP technologies to be introduced to developing countries should be mature, as simple as possible, reliable and safe in operation with low investment requirements and adopted or adoptable to the local needs using, whenever possible, indigenous equipment, raw materials and human resources.

However, a defined policy for the implementation of SHP plants is needed as part of a national strategy in NRSE, national experts with appropriate qualifications, financial resources and, of course, the know-how are required to accelerate SHP application in developing countries. International co-operation and technical assistance can effectively contribute to the transfer and adaptation of technologies concerned.

UNIDO provides technical assistance related to the whole cycle of SHP projects including:

- the preparatory phase (hydrological studies, feasibility studies, project design and engineering, etc.)
- the implementation phase (off-site activity like design and production of equipment, quality control/testing and on-site activity including civil works, construction work, installation/assembly of equipment, etc.)
- the exploitation phase (operation of SHP equipment, spare parts production, maintenance and repair)

and the transfer of complete technology packages or specific parts to be acquired by the respective project.

In order to get technical assistance from UNIDO some procedures should be followed.

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

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

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

The following steps are usually required to initiate a technical assistance co-operation project:

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

Following these preliminary steps, a draft project concept should be prepared jointly with the local SIDFA and forwarded to the UNIDO secretariat for technical review and elaboration into a full-fledged project document according to the established guidelines using the expertise available with UNIDO or/and international experts or international firms depending on the nature of the project. The project document will then be forwarded to the Government and UNDP for approval and signature.

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

5.2 Promotion of Technology and Information Exchange:

UNIOD's promotional activities include the publication and dissemination of documents related to SHP including country papers, technical reports and documents of general interest, such as:

- Mini Hydropower Stations / A Manual for Decision Makers (Ref.No.7)
- Chinese Experience in Mini Hydropower Generation (Ref.No.12)
- Guidelines for the Application of Small Hydraulic Turbines (REf.No.15)
- Report on Standardization for Indigenous Manufacturing of Small Hydroelectric Power Plants (Ref.No.24)

UNIDO has quite good experience in the field of industrial information and has, for over 20 years, been active in providing computerized information packages and in establishing information networks on specific topics including NRSE and SHP as a major component.

The exchange of technological information plays a quite important role and UNIDO is aware of the necessity to avoid duplication of responsibilities and efforts. Therefore, the UNIDO's Energy Information System (EIS) has been created, in order to provide support for the Organization's energy programme and to record its energy activities.

The system's key components are:

- PRAD DATABASE

This necessity for reporting on UNIDO's own activities in the energy sector led to the creation of a computerized information system covering project and other energy-related activities, which has been expanded with the passing years and gained in complexity and coverage. Almost five hundred energy projects have been under implementation since 1980 and form a part of the PRAD computer programme (one component of the EIS). This database provides information on project activities, giving standard data on project number, title, financial aspects, counterpart agencies, as well as an abstract on each project's scope and coverage.

- IDA DATABASE

The IDA (Industrial Development Abstracts) database records, inter alia, technical and final reports which stem from projects, thereby providing a complementary source of information on energy project activities. This existing database is also utilized for providing information on what UNIDO has been doing in the energy sector including SHP.

- ENER DATABASE

This system primarily provides support for INECA (Industrial Energy Conservation Abstracts) which covers information on several activities related to energy conservation in industry, i.e. abstracts of technical papers, energy efficient technologies/equipment, training opportunities, research and development, meetings and consultants/experts. This database will also be available in micro form by mid 1988. The INECA data base is the core of an initiative for creating an information network on industrial energy conservation.

Resulting from a UNDP supported project in the European region, the network concept has found an echo in other regions - initially ASEAN and the Caribbean - and with other organizations. Activities will include utilization of electronic mail for information exchange and the initiation of information exchange modalities between interested parties/nodes within each region and between regions. Envisaged output of the INECA network information structure are manuals/guides on energy technologies and activities related to them, e.g. solar energy and energy conservation in specific sectors; information on UNIDO's energy activities; newsletter INECA and information packages on selected aspects of energy/industry.

6. Conclusions

(1) The acceleration of the industrialization process, the increase of agricultural production and the improvement of living conditions in developing countries requires a well balanced development of the energy sector and their own technological capabilities and human resources in line with national priorities. The mobilization of the indigenous resources and a close international co-operation on the basis of equality and mutual benefit are key factors in this respect.

(2) The demand for energy, particularly electricity will further increase in the future. The developing countries will have an above-proportional growth rate in their energy demand. The share of NRSE in the total balance of energy is growing and hydropower, specifically SHP can make a significant contribution to the energy supply of the industrial sector and agro-industry of developing countries on short and medium terms.

(3) Small-scale hydropower has become an increasingly viable and reliable source of energy with great potential for rural and isolated areas. The developing countries' growing problems of energy deficiency require however, a long-sighted approach to the use of all indigenously exploitable forms of energy including NRSE and SHP as a major component for the promotion of rural development and small-scale industry. SHP must, therefore, be integrated into national development plans taking into account economic, technical and social implications.

(4) The described projects on small-scale hydropower, i.e. the Asia-Pacific RN-SHP and the Regional Centre for SHP at Hangzhou, the Hoha Mini-Hydropower Project in Africa and the Iriri Micro-Hydroelectric Pilot Plant in the Solomon Islands can be regarded as examples several elements of which could be applicable to projects in other regions and countries of the third world particularly with regard to:

- the set-up of regional networks for SHP (RN-SHP/HRC),
- the approach of establishing local manufacturing capacities (HOHA),
- the introduction and application of microelectric development schemes (IRIRI),

promoting the process of industrialization and rural development.

(5) Mature SHP technologies of simple design, reliable operation, low costs, high local content of equipment and materials and adaptable to local conditions have the most promising potential to be applied in developing countries particularly in cases where a whole spectrum of indigenous labour is involved. Local manufacture requires, depending on the SHP components to be produced special knowledge in general mechanical engineering (casting, forging, welding, metal-cutting) and special mechanical engineering with regard to hydraulic systems, governors, penstock, shut-off devices and special electrical engineering (generator, switchgear etc.). Most of these engineering fields are, however, not SHP specific but of multipurpose nature and must be seen in the general context of industrialization. This facilitates the process of entering the manufacturing sector in SHP, using among others, existing workshops or production units and extending available facilities up to the required standard.

(6) Technical assistance activities in SHP should be focussed on the practical implementation of SHP schemes (pilot and demonstration plants) in developing countries and the development of appropriate capacities for local design, manufacture/assembly, R + M, rehabilitation of SHP plants and related equipment through the promotion of the transfer and adaptation of technology, training, exchange of experience and information, co-operative programmes between industrialized and developing countries as well as among developing countries. The involvement of international organizations like UNIDO can facilitate the process of introducing SHP technologies using existing mechanisms and established procedures.

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YEARLY/REGIONAL DISBURSEMENT ON ENERGY
IN THOUSANDS OF US$

	1980	1981	1982	1983	1984	1985	1986	1987	TOTAL
Africa(sub-Sah)	1,330.7	1,496.5	1,614.0	1,378.7	2,320.8	2,147.7	2,088.8	1,449.4	13,813.6
Asia/Pacific	1,627.7	1,310.3	3,160.6	2,148.3	2,348.0	3,274.6	4,348.2	5,292.6	23,510.4
Latin America	330.0	96.4	301.5	510.5	405.6	583.8	450.8	585.3	3,263.8
Europe	650.4	241.3	396.8	453.5	552.0	329.8	563.4	561.5	3,748.7
Arab Countries	0.0	0.0	166.0	232.5	356.7	231.9	1,209.3	964.2	3,160.7
Global/Interreg	652.3	471.9	638.2	723.3	731.1	725.0	1,112.4	1,057.0	6,111.1
TOTAL	4,591.2	3,616.4	6,277.0	5,446.9	6,720.2	7,292.8	9,754.0	9,908.0	53,608.4
NUMBER OF PROJECTS	59	74	90	103	93	101	110	113	466
AVERAGE PER PROJECT	77.8	48.9	69.7	52.9	72.3	72.2	88.7	87.7	115.0

PERCENTAGE OF TOTAL TA

	1980	1981	1982	1983	1984	1985	1986	1987
Africa(sub-Sah)	1.7	1.7	1.8	1.8	2.6	2.3	2.0	1.4
Asia/Pacific	2.2	1.5	3.5	2.7	2.6	3.7	4.3	5.4
Latin America	0.4	0.1	0.3	0.6	0.5	0.7	0.4	0.6
Europe	0.9	0.2	0.5	0.6	0.7	0.3	0.6	0.6
Arab Countries	0.0	0.0	0.2	0.3	0.5	0.4	1.2	1.0
Global/Interreg	0.9	0.6	0.6	1.0	0.8	1.0	1.1	1.1
TOTAL %	6.1	4.1	8.0	7.0	7.7	8.4	9.6	10.1
TOTAL TA IN MILLIONS	$75.1	$88.5	$81.9	$78.0	$87.2	$84.5	$101.9	$97.7

PERCENTAGE SHARE OF REGIONS IN TOTAL ENERGY DISBURSEMENT

	1980	1981	1982	1983	1984	1985	1986	1987
Africa(sub-Sah)	29.0	41.4	25.7	25.3	34.6	27.7	21.0	14.5
Asia/Pacific	35.5	36.2	50.4	39.4	34.9	43.8	46.2	54.0
Latin America	7.2	2.7	4.8	9.4	6.0	7.6	5.0	6.0
Europe	14.2	6.7	6.3	8.3	8.2	4.2	5.7	6.0
Arab Countries	0.0	0.0	2.6	4.3	5.3	5.4	10.7	10.0
Global/Interreg	14.2	13.0	10.2	13.3	10.9	11.3	11.4	10.5
TOTAL	100	100	100	100	100	100	100	100

<u>Annex 1</u>
<u>Source: Ref. No.32</u>

STATISTICS TAKEN FROM UNIDO'S ENERGY INFORMATION SYSTEM (EIS)
HYDROPOWER DISBURSEMENT
US $ THOUSANDS

	1980	1981	1982	1983	1984	1985	1986	1987	TOTAL
Africa(sub-Sah)	0.000	0.000	220.000	189.000	141.000	785.000	200.000	82.000	1637.000
Asia/Pacific	0.000	172.000	151.000	241.000	159.000	139.000	309.000	257.000	1428.000
Latin America	47.000	37.000	0.000	32.000	50.000	0.000	0.000	0.000	166.000
Europe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.000	2.000
Arab Countries	0.000	0.000	0.000	0.000	0.000	0.000	143.000	23.000	166.000
Global/Interreg	187.000	43.000	0.000	36.000	33.000	35.000	66.000	243.000	643.000
TOTAL	234.000	252.000	371.000	508.000	383.000	959.000	718.000	617.000	4042.000

SOLAR ENERGY DISBURSEMENT
US$ THOUSANDS

	1980	1981	1982	1983	1984	1985	1986	1987	TOTAL
Africa(sub-Sah)	31.000	201.000	187.000	144.000	25.000	103.000	56.000	69.000	736.000
Asia/Pacific	3.000	40.000	1181.000	133.000	169.000	35.000	92.000	1134.000	2787.000
Latin America	5.000	36.000	8.000	15.000	13.000	22.000	27.000	50.000	176.000
Europe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arab Countries	0.000	0.000	0.000	169.000	49.000	0.000	32.000	56.000	306.000
Global/Interreg	0.000	0.000	19.000	97.000	0.000	0.000	10.000	0.000	126.000
TOTAL	39.000	277.000	1315.000	558.000	256.000	160.000	217.000	1309.000	4131.000

BIOENERGY DISBURSEMENT
US$ THOUSANDS

	1980	1981	1982	1983	1984	1985	1986	1987	TOTAL
Africa(sub-Sah)	67.000	138.000	55.000	23.000	20.000	220.000	79.000	37.000	639.000
Asia/Pacific	7.000	377.000	1295.000	652.000	764.000	1154.000	593.000	418.000	5260.000
Latin America	9.000	15.000	194.000	159.000	37.000	185.000	119.000	109.000	827.000
Europe	0.000	0.000	0.000	0.000	246.000	67.000	165.000	90.000	568.000
Arab Countries	8.000	4.000	70.000	6.000	35.000	34.000	63.000	156.000	376.000
Global/Interreg	131.000	85.000	132.000	23.000	215.000	137.000	341.000	29.000	1093.000
TOTAL	222.000	619.000	1746.000	863.000	1317.000	1797.000	1360.000	839.000	8763.000

WIND ENERGY DISBURSEMENT
US$ THOUSANDS

	1980	1981	1982	1983	1984	1985	1986	1987	TOTAL
Africa(sub-Sah)	35.000	16.000	15.000	0.000	0.000	0.000	0.000	21.000	87.000
Asia/Pacific	0.000	0.000	0.000	0.000	0.000	11.000	0.053	0.000	11.053
Latin America	0.000	0.000	0.000	0.000	0.000	0.000	0.000	71.000	71.000
Europe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Arab Countries	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8.000	8.000
Global/Interreg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL	35.000	16.000	15.000	0.000	0.000	11.000	0.053	160.000	177.053

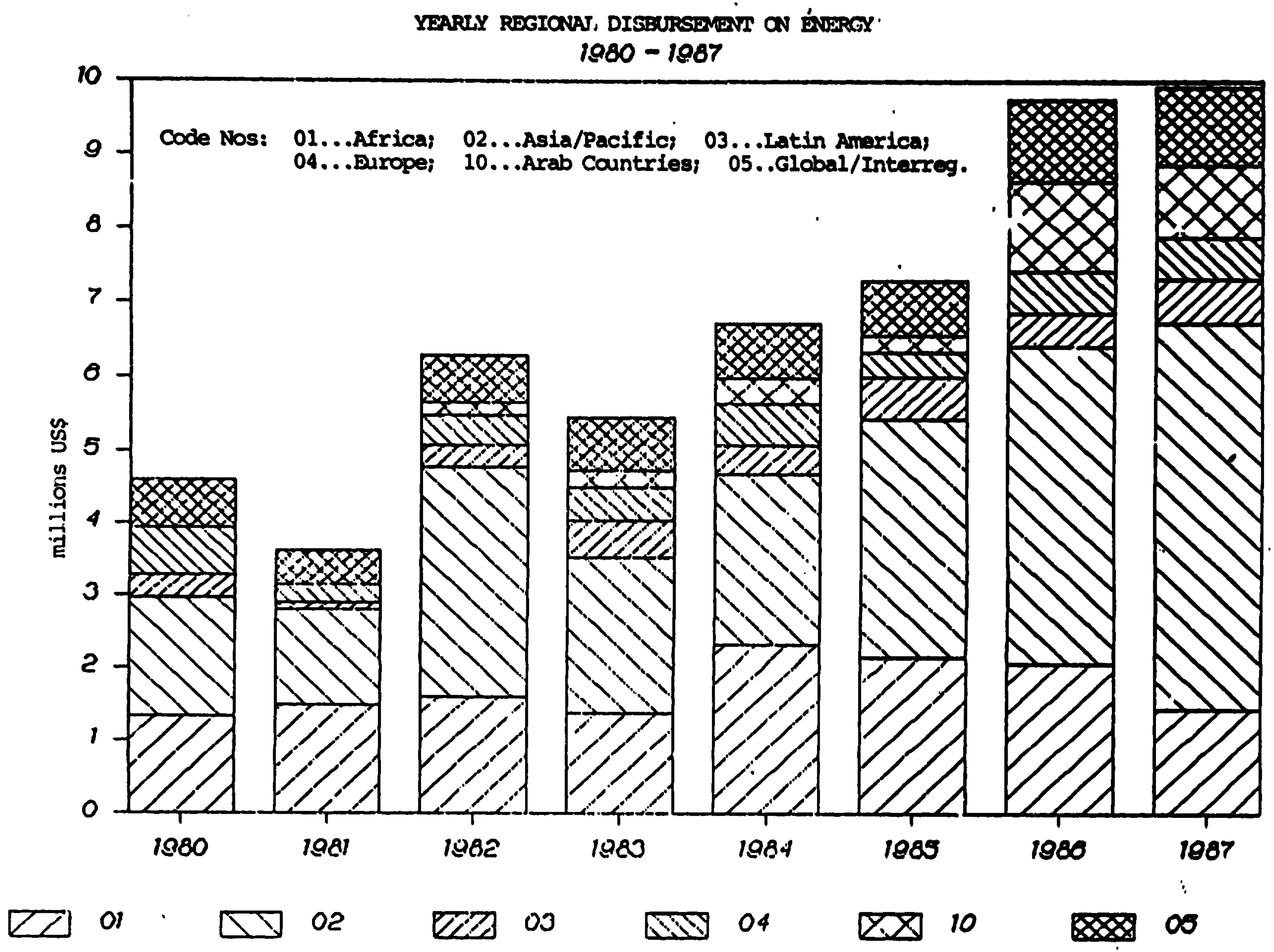
TOTAL NRSE DISBURSEMENT
by source

	1980	1981	1982	1983	1984	1985	1986	1987	TOTAL
HYDRO	234.000	252.000	371.000	508.000	383.000	959.000	718.000	617.000	4042.000
SOLAR	39.000	277.000	1316.000	558.000	256.000	160.000	217.000	1309.000	4131.000
BIO	222.000	619.000	1746.000	863.000	1317.000	1797.000	1360.000	839.000	8763.000
WIND	35.000	16.000	15.000	0.000	0.000	11.000	0.053	100.000	177.053
TOTAL NRSE	530.000	1164.000	3447.000	1929.000	1956.000	2927.000	2295.053	2865.000	17113.053
TOTAL ENERGY	4591.000	3616.000	6277.000	5447.000	6720.000	7293.000	8754.000	9910.000	

TOTAL NRSE DISBURSEMENT
by region

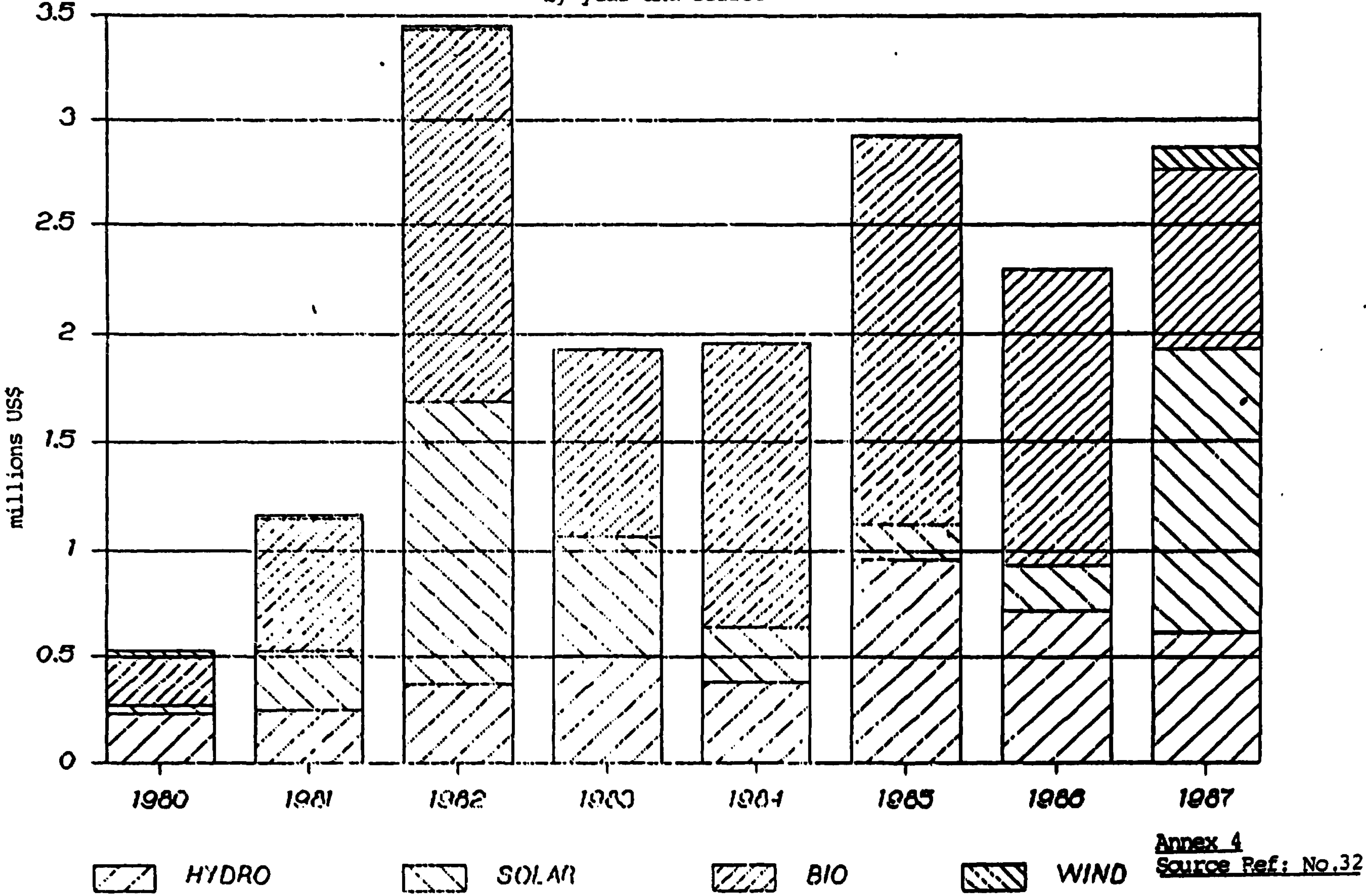
	HYDRO	SOLAR	BIO	WIND	TOTAL
Africa(sub-Sah)	1637.000	736.000	639.000	87.000	3099.000
Asia/Pacific	1428.000	2787.000	5260.000	11.053	9486.053
Latin America	166.000	176.000	827.000	71.000	1240.000
Europe	2.000	0.000	568.000	0.000	570.000
Arab Countries	166.000	306.000	376.000	8.000	856.000
Global/Interreg	643.000	126.000	1093.000	0.000	1862.000

Annex 2
Source: Ref: No.32



Annex 3
Source: Ref. No.32

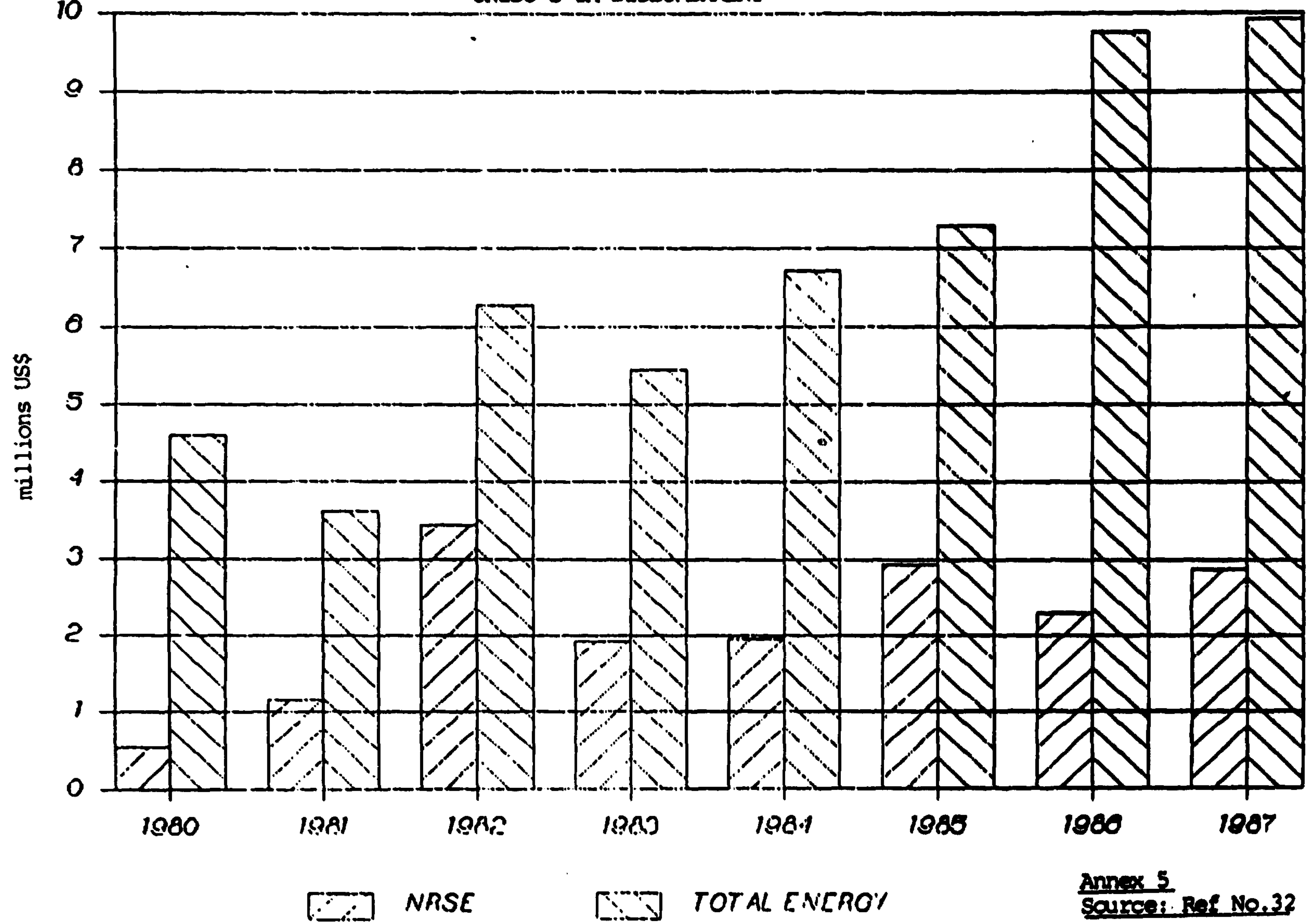
UNIDO's NRSE DISBURSEMENTS
by year and source



Annex 4
Source Ref: No.32

NRSE COMPARED WITH TOTAL ENERGY

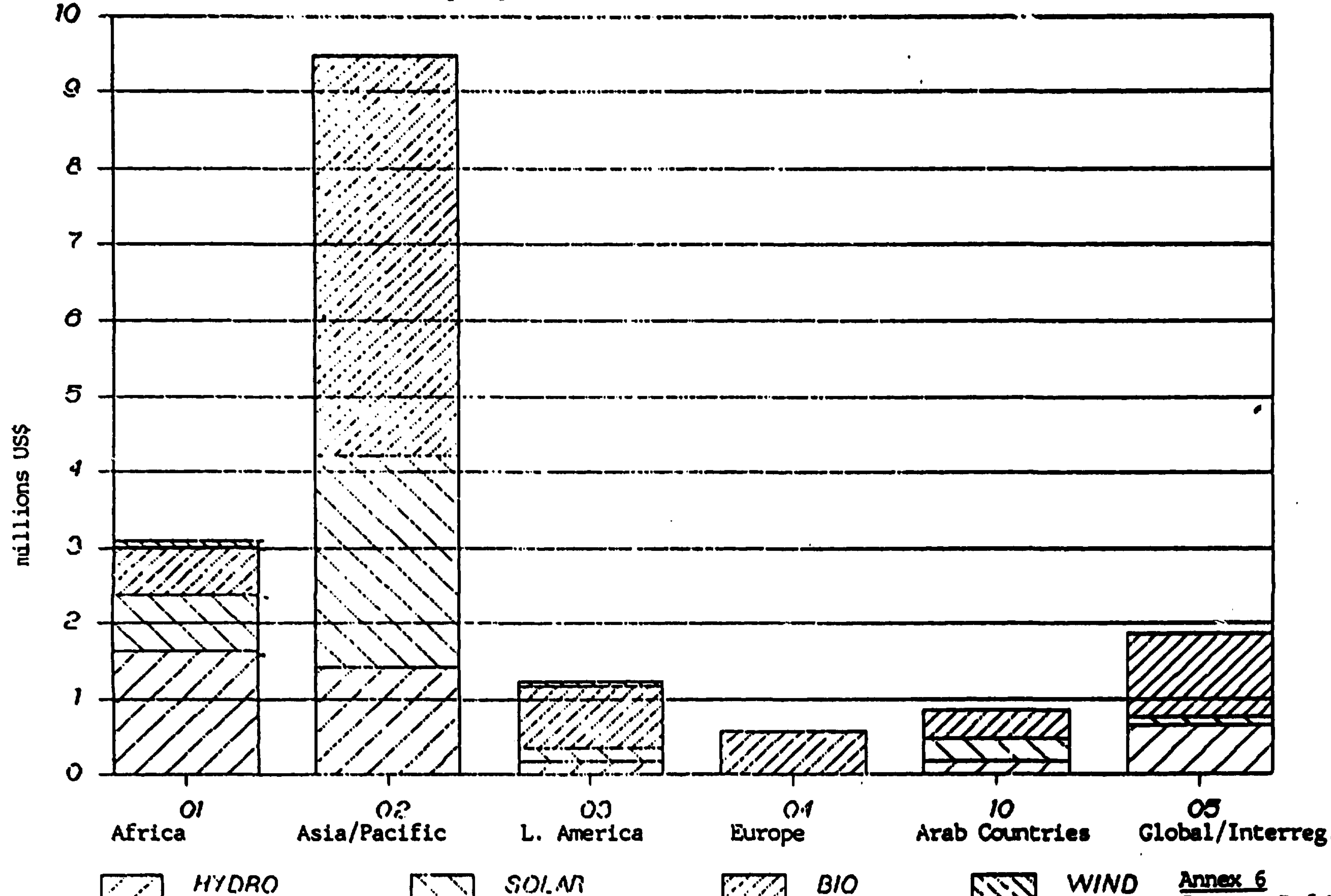
UNIDO's TA DISBURSEMENT



Annex 5

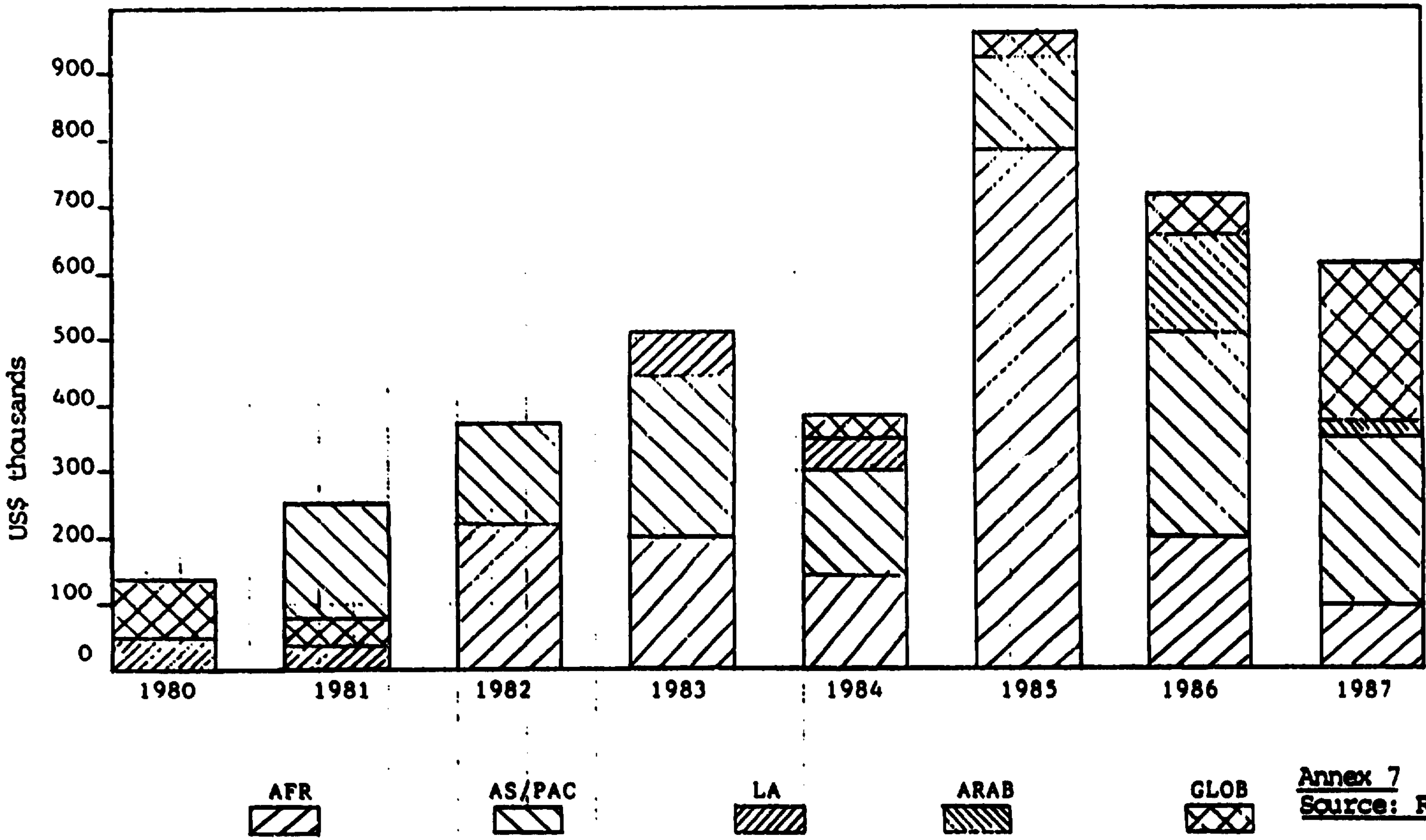
Source: Ref No.32

UNIDO's NRSE DISBURSEMENT
by region and source



Annex 6
Source: Ref No.32

UNIDO's Technical Co-operation programme on hydropower 1980-1987 - total expenditures; percentage share of regions.



Annex 7
Source: Ref. No.32

HOHA Hydro Power Plant
Main Characteristics

Hydrology	Catchment area		184	km²
	Rainfall		1280	mm
	Average flows	Annual discharge	1.63	m³/s
		Wet season flow	3.38	m³/s
		Dry season flow	0.74	m³/s
	Spillway design flood		30.0	m³/s
Weir	Type	Fixed sill, masonry		
	Head	approx.	1.5	m
Intake	Type	Lateral, Diversion		
	Discharge		0.6	m³/s
	Gate	Sliding gate (manual operation)		
	Features	Skimming wall, flushing channel		
Head-race	Type	Open channel, length	2.4	km
Canal	Cross-section	Trapezoidal, lined	0.88	m²
	Gradient		1	per mill
Forebay	Type	Open bay, volume	2500	m³
	Cross-section	Trapezoidal, lined		
	Features	Spillway, desilting pipe, intake structure		
Penstock	Type	Double steel pipe		
	Diameter x length		2 x 0.40 x 265	m
Power Plant	Installed capacity	Phase 1	300	kW
		Phase 2	350	kW
		Total	650	kW
Turbines	Type	Horizontal Francis		
	No. of Units		2	
	Gross Head		135	m
	Rated Speed		1500	RPM
Generators	Type	Horizontal	50	Hz
	Capacity	Phase 1	525	kVA
		Phase 2	475	kVA
	Power Factor		0.8	
	Voltage		400	V
Transformer	Type	Star-Delta		
	Frequency		50	Hz
	Rated Capacity	Phase 1	500	kVA
		Phase 2	1000	kVA
	Rated Voltage		0.4/15	kV
Transmission line	Type	Wood-poles		
	Voltage		15	kV
	Length	approx.	10.0	km

Annex 8
Source: Ref No.22