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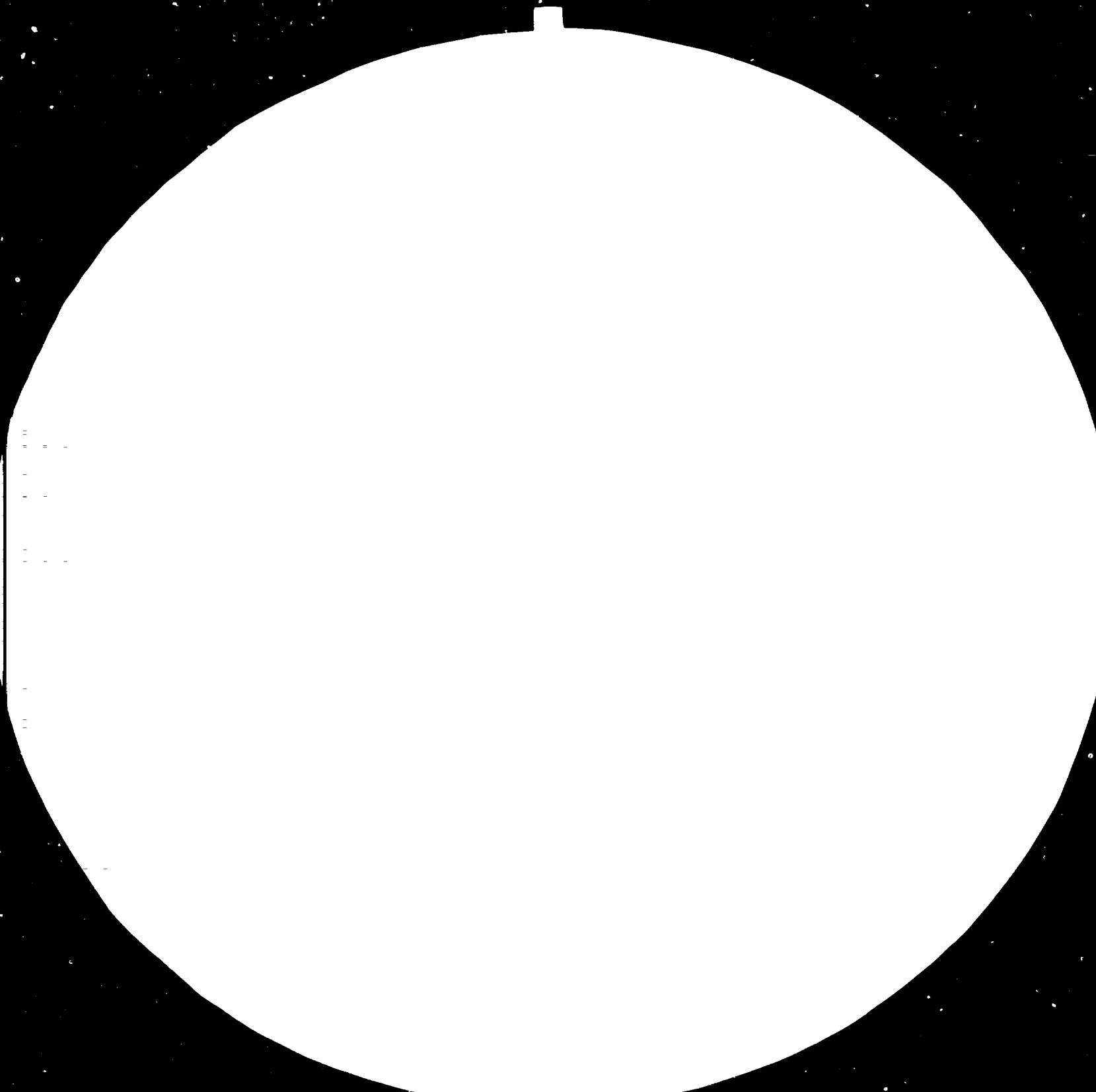
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DEVELOPMENT OF SMALL HYDRO POWER
in the Republic of Zambia*

by

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Brief Characterization of the Electric Power Supply of Zambia

Low-cost production and distribution of electric energy from hydro-power is a prime factor in the power supply of Zambia. The three large hydro-power stations

	<u>Station capacity</u>	<u>Yearly generated energy</u>
Kariba North	approx. 600 MW	approx. 3300 GWh/a
Kafue Gorge	approx. 960 MW	approx. 4200 GWh/a
Victoria	approx. 110 MW	approx. 700 GWh/a

produce approx. 96% of all electric energy generated in the country. The distribution is effected by means of a national interconnected grid with voltages between 330 kV and 11kV.

Electric energy is supplied to the consumer at a standard tariff valid for the entire country and at comparatively very low energy prices (Ngwee/kWh); this is of special importance for the development of Zambia.

Zambia owes the low-cost energy supply to its major river systems:

Zambezi and Kafue rivers.

The development of hydro-power in Zambia over the past 25 years has progressed so far that a substantial export of electric energy from Zambia to neighbouring states, mainly Zimbabwe, takes place. At present a total of over 400 MW and approx. 3,200 GWh per year is exported, which corresponds to approx. 64% of Zambia's own requirements.

Activities and Organizational Set-up

At Hangzhou, China/Manila, Philippines UNIDO Second Seminar-Workshop/Study Tour held in October/November 1980, I reported about the follow-up action Zambia was making in the development of Mini-hydropower Generation for the rural areas as a result of the recommendations of Kathmandu Seminar-Workshop held in September 1979.

In recognition to improve life conditions of rural population in respect of decentralization of hydro-power generation and in response to the United Nations Conference on New and Renewable Sources of Energy held in Nairobi, Kenya in August 1981 the National Energy Council and the new Department of Energy are now operational.

The National Energy Council is the national forum where energy projects and policy will be initiated, while the Department of Energy will be responsible to implement the decisions of the Energy Council resting with the Minister for Power to whom the Council is advisory. Rural Electrification in Zambia is financed by the Central Government through the Ministry responsible for power by grants and subsidies to Zambia Electricity Supply Corporation a parastatal organization which is at present the sole agent for development of rural electrification which is executed normally by outside contractors.

Methodology for Feasibility Studies

Pre-feasibility Study was recently completed on the development of small-hydro power generation in NorthWestern Province of Zambia by Decon, Deutsche Energie-Consult of the Federal Republic of Germany, under technical assistance programme between Zambia Government and West Germany Government. It is the accepted decision of the Ministry for Power to replace the existing small diesel power stations with SHP or MHG in the rural North Western Province and the rest of the rural centres of the rest of the Provinces in Zambia.

The present study was elaborated on behalf of ZESCO in the framework of German Financial Cooperation with Zambia. The objective of this study, as defined with ZESCO, was to investigate the possibilities and limitations of the utilization of hydro power in the Northwest of Zambia with the purpose to replace the existing diesel power stations of the following townships:

- Mwinilunga
- Kabompo
- Zambezi
- Kanemba
- Kaoma

With the exception of Kaoma, which belongs to the Western Province, all other townships are located in the North-Western Province of Zambia. Lukulu, located in the Western Province, a township which up to this date has no public electricity supply was to be included in the study.

The isolated networks existing in the above townships are all 11/0.4 kV distribution systems fed by diesel generators. These networks are about 10 years old and have been constructed by ZESCO. They are in excellent conditions and of exemplary technical as well as aesthetic construction.

The diesel generators, originally used for the supply of these townships are USSR-made. In 1971 four each a maximum continuous rating (MCR) of approx. 110 kW have been installed in Mwinilunga, Kabompo, Zambezi and Kasempa. These aggregates have meanwhile surpassed their usual service life. Because of insufficient spare-parts supply and poor service instructions (in Russian only) these diesel generators are in bad condition and have partially been replaced or complemented by movable units of various origin (capacity: approx. 100 - 200 kW).

In order to secure the electricity supply of the townships of the project area, a substitute investment over the next two to three years seems necessary for replacing almost all installed diesel generators of the investigated diesel power stations.

The values over the past year of annual peak load, energy generation and load factor are as follows:

	Installed Capacity (kVA)	Peak Load (kW)	Annual Electric Energy Generation (MWh/a)	Annual Load Factor (%)
Mwinilunga	812	300	957	37
Kabompo	725	290	1,036	41
Zambezi	1.050	310	1,360	50
Kasempa	750	290	900	27
Kaoma	490	240	808	38

Since the installed capacity is insufficient to meet the demand and the peak load therefore limited by means of load shedding, the values for Kaoma can only be compared to a certain degree with those of the other towns.

The increase of the annual electric energy generation of the townships over the past years was mostly in the rate of 2 to 3 % but, partially even lower. The high portion of productively used electricity (approx. 80 to 90 %) is a characteristic feature of all townships. The socio-economy of the project area is marked by

- very sparse population
- dominating importance of subsistence agriculture
- very few production centres with very few employed labourers
- bad traffic roads and great distances between the places
- sufficient public health and educational institutions
- the supply of the population with foodstuffs and everyday consumer goods needs to be improved

A strong migration trend of the male population in the project area to the Copperbelt and Lusaka is to be noted.

The load forecast for the investigated townships was worked out on the basis of an annual increase of 2% p.a. for the first ten years and of 3% p.a. for the remaining 15 years up to the forecast horizon.

Mwinilunga	:	approx.	490 kW
Kabompo	:	approx.	520 kW
Zambezi	:	approx.	560 kW
Kasempa	:	approx.	580 kW
Kadma	:	approx.	410 kW
Lukulu	:	approx.	250 kW

The concentrated support of the field studies by ZESCO (making available an airplane, cross-country cars, etc.) made it possible inspite of difficult traffic conditions to obtain a comprehensive view of the possibilities to utilize hydro power in the project area.

Characteristic for the North-West of Zambia is a terrain ascending to an altitude of up to 500 m above the typical Zambian Plateau and heavier rainfalls. This results in relatively fair conditions for the construction of hydro power stations; these conditions become, however, less favourable further south.

Although the rivers in this region allow in part for an expansion of the plant capacity up to 20 or 30 MW, the sites proposed have purposely been adapted to the local demands. Two sizes typical for the power stations have been chosen:

Size 1:	Installed capacity:	approx. 50 to 200 kW
Size 2:	Installed capacity:	approx. 500 to 2,000 kW

All hydro power stations have been foreseen as run-off river power stations in order to meet the following requirements:

- as little disruption of the countryside as possible
- as little detraction from the use of the site around the power stations
- avoidance of extensive water reservoirs (high vaporization)
- low construction costs per site
- limitation of the dimensions of flood protection installations.

When selecting the sites special attention has been paid to their proximity to the load centres in order to minimize the cost for the necessary transmission lines.

In this study the following hydro power station sites have been investigated in more detail:

- 1) Mwinilunga Bridge (2 x 600 kW)
- 2) Kabompo-Manyinga Bridge (1 x 100 kW)
- 3) Kabompo-Chekota Falls (2 x 600 kW)
- 4) Zambezi-Chavuma Falls (2 x 600 kW)
- 5) Kasempa Bridge (alternatively 1 x 100 kW
or 1 x 230 kW).

Standardized power house structures, adapted to the turbines installed, have been proposed as far as possible for the development of the sites. Materials available at the site will be used for dam structures. For all plants the share of local currency is above 60%.

The relation of discharge (Q) to height of fall (H) permits the installation of three types of turbines:

- Flow-through Turbines (type: Oasberger)
- Francis-Shaft-Turbines
- Kaplan-Tube-Turbines.

With regard to the basic conception the proposed structures and equipment are construed in form of a "MAT-technique" (mechanical assembly technique). Therefore they can be utilized with slight modifications at any other hydro power station site in the project area.

For the hydro power stations the following investment cost including transmission lines to the townships to be supplied have been estimated:

- | | | | | |
|---------------------------------------|---|-----------------|---|--------|
| 1. Mwinilunga Bridge | : | 8.8 million DM | = | K 3.12 |
| 2. Manyinga Bridge | : | 4.6 million DM | = | K 1.63 |
| 3. Chekota Falls | : | 9.3 million DM | = | K 3.30 |
| 4. Chavuma Falls | : | 14.0 million DM | = | K 7.96 |
| 5. Kasempa Bridge | : | 4.7 million DM | = | K 1.66 |
| 5a. Kasempa Bridge
- Alternative - | : | 5.7 million DM | = | K 1.0 |

The connection of the townships to the national grid has also been evaluated under the calculation of profitability. It was found, however, that the dynamic generation cost to be expected are three times exceeding those of isolated networks with diesel generators. This alternative has therefore been given further consideration in other calculations.

The findings of the study prove the expected strong dependency of the dynamic generation cost from the rate of interest. With a rate of 8 % the hydro power stations

- Mwinilunge Bridge (Alternative 3.1)
 - Chakata Falls (Alternative 3.3)
 - Kasempa Bridge (Alternative 3.5a)
- are more favourable than diesel power stations only.

With regard to its economical operation the Chavuma Falls power station suffers from the great distance (75 km) to the township of Zambezi as its principle load demand. Possibly the feasibility study will show more favourable results since the estimates of investment costs include high contingencies because of the uncertainties of the basic data.

The following dynamic generation cost (DM/MWh) have been calculated:

	Interest rate 8 %		Interest rate 5%	
	Hydro Power	Diesel Power	Hydro Power	Diesel Power
1. Manyinga Bridge	838	806	767	807
2. Chavuma Falls	825	770	635	776
3. Kasempa Bridge	915	867	818	854

Finland has advanced technology in the design and economic application of MHG power generation units which could find extensive use in remote areas of the Third World Countries which have no local designing and manufacturing technological base of MHG equipment.

Finland designs and manufactures Kaplan turbines for low-head application and some francis turbines for medium heads, as well as gates and other structures for hydro electric power stations. The capacity of turbines ranges from 100 kW to 50 MW. Under technical agreement with Finland. A project team of experts will arrive in Zambia at the beginning of March 1983 to carry out a Feasibility Study in the rest of the country on Power System Development for 4-5 months period. Except in Western Province were Norway might carry out a Feasibility Study on Mini-hydropower generation (Rural Electrification).

Techniques for determining limits of costs reduction compatible viability and utility - Recommendations

The preceding comments have shown that the six townships investigated in the North-Western Province and Western Province will have to be assessed differently with regard to alternatives to the electric energy supply from diesel generators.

The following ascertainment is valid for all locations:

When connecting the places investigated to the national grid the dynamic generation costs are so high that within a measurable time this alternative can not be considered an economical one, although according to information obtained from ZESCO generating and transmission costs within this grid are to be calculated with 14.14 DM/MWh (0.52 Ngwee/kWh). At an 8 % discounting rate these costs are three times above those to be expected for the supply from diesel generators in isolated networks, even though when taking into account a 2% annual actual price increase for the diesel oil over 25 years. These ascertainments need verification if in future

- the energy and power demand produces over many years high growth rates in the investigated townships which are way above the average of all of Zambia.
- the annual increase of the costs for diesel oil is substantially higher than the general cost of living in Zambia
- the maximum power demand amounts to at least 2 MW and the energy demand to at least 7 GWh/a in each place.

Due to the geographical location of the townships the assessment of the use of mini hydro power for the places in the North-West Province is basically positive.

For each of the other places one or several possibilities for the use of hydro power have been evaluated. The findings show a strong dependence of the alternatives upon the rate of interest.

At an interest rate of 8% and 5 % the following dynamic generation cost (DM/MWh) have been calculated:

	Interest rate 8%		Interest rate 5%	
	Hydro Power	Diesel Power	Hydro Power	Diesel Power
1. Mwinilunga Bridge	790	792	614	791
2. Manyinga Bridge	833	806	767	807
3. Chakata Falls	783	806	612	807
4. Chavuma Falls	825	770	635	776
5. Kasempa Bridge	915	867	818	854
5a. Kasempa Bridge - Alternative -	814	367	683	854

taking an interest rate of 8% as base for evaluation the following order of priority results.

1. Kabompo - Alternative 3.3 - Hydro Power Station Chakata Falls (installed capacity: 1,200 kW)
2. Mwinilunga - Alternative 3.1 - Hydro Power Station Mwinilunga Bridge (installed capacity: 1,200 kW)
3. Kasempa - Alternative 3.5a - Hydro Power Station Kasempa Bridge (installed capacity: 230 kW)
4. Zambezi - Alternative 3.4 - Hydro Power Station Chavuma Falls (installed capacity: 1,200 kW)
5. Kabompo - Alternative 3.2 - Hydro Power Station Chakata Falls (installed capacity: 1,200 kW)
6. Kasempa - Alternative 3.5 - Hydro Power Station Kasempa Bridge (installed capacity: 100 kW).

At this interest rate of 8% the dynamic generation cost of the hydro power stations:

- Manyinga Bridge -Alternative 3.2
- Chavuma Falls -Alternative 3.4
- Kasempa Bridge -Alternative 3.5

are higher than those ones which are calculated for the supply from diesel generators. The last three alternatives of the shown priority list cannot be recommended on the basis of these results for a further investigation in a feasibility study.

When looking at the supply of electric energy as an infra-structural measure of special importance and therefore taking a 5% interest rate as the basis for evaluation, then the order of priority changes as follows:

1. Kabompo - Alternative 3.3
2. Mwinilunga - Alternative 3.1
3. Zambezi - Alternative 3.4
4. Kasempa - Alternative 3.5a
5. Kabompo - Alternative 3.2
6. Kasempa - Alternative 3.5

The diagrams presented show the following internal rates of return for the investigated Alternatives:

- Kasempa Bridge : 9.3 %
- Chakata Falls : 8.4 %
- Mwinilunga Bridge : 8.1 %

- Chevume-Falls : 7.2 %
- Manyinga Bridge : 6.7 %
- Kasempa Bridge : 6.3 %

When rating these findings the following will have to be taken into consideration:

- The cost estimates for the hydro power stations include high contingencies due to the uncertainties at the present planning stage. A feasibility study may possibly produce more favourable results.
- A techno-economical optimization regarding
 - height of dams
 - size of turbines
 - number of turbines

will have to be determined in a feasibility study. The facts on hand are insufficient.

- The sites of the hydro power stations may still be slightly altered in a feasibility study upon closer exploration and more exact knowledge on the geology and topography.

On the basis of these results it can be recommended to investigate the sites of

- Mwinilunga Bridge
- Chakata Falls
- Kasempa Bridge

in the framework of a feasibility study. The site of Chevume Falls should also be included, if possible, in this study.

It is expected that more detailed site investigations show more favourable results for this power station.

Regarding site survey, necessary for obtaining the required detailed data, ZESCO has agreed to finance the corresponding topographical investigation.

Centralized and Decentralized MHG Systems

MHG Systems in Zambia are necessary for rural multi purpose projects especially that Government is actively going to introduce village industry. But although Zambia may have its own way of applying the MHG technology, and was pursuing its own RLD projects, it is quite alert to the possibilities of learning from others at this Workshop.

Zambia will were necessary continue to extend centralized power systems especially for major rural industry and farming. At present farm business is done under several restricting scarce factors. An attempt was being made to select an optimum crop-plan for the farms in the country. There is need to analyse various parameters of the energy needs for increased agricultural production in Zambia by irrigation.

Local Design and Manufacture of equipment and auxiliaries for MHG

After completing the current feasibility studies for MHG. Government will be asked to decide on the strategy for implementation of rural electrification programme. Due to Zambia's present inexperience in the design and manufacture of equipment, it might be necessary to approach UNIDO/UNDP to give Zambia economic/technical assistance in the development of MHG - It might be time saving to obtain the best design of MHG equipment from UNIDO for consideration and development by Zambia Government.

The creation of National Energy Council along with the Department of Energy will definitely alter the present attitudes to Rural Electrification for the better future of rural children in Zambia.

We expect the United Nations Industrial Development Organization to support and reinforce national efforts, especially of developing countries. But developing countries must strengthen their collective self-reliance. Technical Co-operation, the sharing of training facilities, the exchange of experts and information, joint R L D programmes including the testing of equipment, mutually beneficial consultancy and related measures are ways to make self-reliance a reality. A freer flow of technical information and a more liberal transfer of technology from high pressure areas to depressed regions of the economic atlas should become a tenet of new world order.

