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AGENCY FOR INTERNATIONAL DEVELOPMENT

IMPROVED WATER PUMPING/ WATER LIFTING SYSTEMS FOR AFRICA.

Comparison of photovoltaic pumps with wind, diesel, animal and human pumping systems for irrigation.

A global project to assess the viability of solar pumping was undertaken by IT Power/Halcrow for the UNDP/World Bank in the period 1979 to 1983. One of the principal objectives of the second phase of the work (1981-1983) was to examine in detail the economic viability of solar pumps, compared with the alternatives.

The main objectives of the system applications and economic studies were to identify the technical and economic circumstances under which solar water pumps become viable. This was achieved through a systematic and structured analysis of and comparison between the economics of solar pumps and alternative prime-movers with different conveyance, distribution and storage options selected to meet the following three requirements:

- o irrigation applications, where water is raised through static lifts in the range 2m to 10m to suit land ares of 0.25 to 4 ha
- o village water supply applications, where water is raised through static lifts in the range 15m to 30m to serve populations of 375 to 1500 people.
- o livestock water supply applications, where water is raised through static lifts in the range 15m to 30m for herds of 1000 to 4000 animals.

For each case studied, the output water cost (in US cents per cubic meter) was calculated. This is the uniform annual sum equivalent to the Present Worth of all the life cycle costs (capital and recurrent) for a specified period of analysis and discount range, divided by the total volume of useful water pumped in a year. The water costs quoted are for delivery to the crop (not the field)

Two computer based mathematical modules were developed, one for the irrigation applications and the other for the water supply applications. A modular approach was adopted for both models utilizing components for water source, power source, pumps, water storage unit, conveyance or distribution method and field application method (the last only for the irrigation model). The models allow for the specification of the technical cost features of each component and their combination in appropriate order for each of a number of scenarios studied.

The six energy sources considered were solar, wind, diesel fuel, kerosene fuel, animal and human. Two cases were considered for the diesel and kerosene engines: a "low" recurrent cost case which represents the best which can be expected under good conditions in a developing country, and a "high" recurrent cost case representative of realistic performance under normal field conditions, where engines are usually run below optimum efficiency and with poor servicing, maintenance, and operating management. For irrigation applications the time a person spent handpumping was given a value, whereas for village water supply it was assumed to be zero.

Three basic types of analysis were carried out:

- o Baseline studies, chosen to represent typical conditions under which six pumping system options were compared in the context of their irrigation or water supply applications.
- o Sensitivity analyses, in which some of the input parameters used in the baseline case were systematically changed to investigate their relative importance to the output water costs;
- o country specific case studies in which parameters representative of three countries - Bangladesh, Kenya and Thailand - were used to assess the effect of local conditions on the relative competitiveness of the different pumping systems.

Data for the baseline studies were collected from international sources, while information on water use and practice and costs in Bangladesh, Kenya and Thailand was obtained through detailed questionnaires prepared especially for this study. Capital costs were expressed in a form which enabled the variation of cost with size or power output to be related, and recurrent costs were calculated in three parts ie. replacement of an item after the end of its operating life, maintenance and repair, and operation. International cost data were deemed to be free of taxes and subsidies. All economic comparisons were carried out on classical DCF principles, using a real discount rate of 10% and a period of analysis of 30 years.

For each scenario incorporating wind and solar pumps, the systems were sized as necessary to meet the mean daily volume of water required for an assumed demand in the critical month. For irrigation this is the month in which the ratio of the renewable energy available to the hydraulic energy required is a minimum. For animal pump and handpump scenarios, systems were sized to meet the maximum mean daily water demand, while the size of the diesel and kerosene engines were fixed at nominal rated 2.5 kW shaft power.

The studies also included comparisons with the costs of water delivered by solar pumping systems with the performance and cost characteristics defined for the Target and Potential cases. For the irrigation studies the baseline models consisted of the size different prime movers coupled with appropriate selections from three methods of water conveyance (earth channel, concrete line channel and pipes) and two methods of application to the crop (furrows or trickle pipes) on a 2 hectare plot. The solar and wind scenarios were considered with and without half day storage, and the model allowed for drawdown in the water source and head loss in the channels and pipes. The baseline models were run for static lifts of 2m and 7m. The model was used to compute the unit cost of water provided under each scenario to meet the net crop irrigation water requirement for a baseline cropping pattern (peak requirement 6mm/day). This involved the analyses of 60 scenarios. As part of the baseline studies, the irrigation was varied from 0.25 to 4 hectares and the input values for which the output water cost was a minimum were noted. In order to make a fair comparison between different pumping methods, a further analysis was undertaken to establish the cost of supplying a 2 hectare area using the appropriate number of each type of optimally sized system. It was apparent from the comparison that kerosene fuelled engines are less cost-effective than diesel fuelled engines and hence they were not considered further. A general comparison was made of the output water cost with a global target for the upper limit to the economic cost of water of 10 cents per cubic meter (delivered to crop).

Sensitivity studies considered the combination of optimally sized systems required to supply a 2 hectare irrigation area. Four groups of parameters were considered (climate, agricultural and technical factors, costs and economic) and the percentage change from the baseline unit water costs was calculated for variation of each individual major parameter in each of the groups by $\pm$ 50% (except where this was physically impossible). Systems with storage were not examined as they were always more expensive than similar systems without storage. As expected, one of the most important parameters was static lift.

For the three country case studies, data on local costs, cropping patterns and meteorological conditions were abstrated from the detailed questionnaires completed for the Project by local organisations or individuals in the three selected countries. The unit cost of water delivered to the crop by each pumping system for the basline and country case studies for a 2m and 7m static lift was calculated using the same general method adopted for the baseline sensitivity analyses although the input cost data include subsidies and taxes.

Annex 1 is chapter 8 of the Final Report on this project (Ref 1) which presents the results of the irrigation studies. Full details of data used and analytical techniques are given in a supporting document to this report (Ref 2). Following completion of this project a Handbook on Solar Pumping was published (Ref 3).

References:

1. Sir William Halcrow & Partners in association with Intermediate Technology Power Limited. "Small-scale Solar-Powered Pumping Systems: the Technology, its economics and advancement. Main Report". The World Bank, June 1983.

2. Supporting Document 2 (to ref 1) "Economic Evaluation of Solar Water Pumps". The World Bank, June 1983.

3. J.P.Kenna & W.B.Gillett. " Solar Water Pumping, A Handbook". Intermediate Technology Publications, London 1985.