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Small-Scale Pumping for Agriculture in Developing Countries

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There have been and still are a large number of photovoltaic (PV) powered pumping demonstrations and applications throughout the world. It has been estimated that approximately 700 PV powered pumping systems have been installed around the developing world in the last three years, and there are possibly another 100 systems in use in the developed world. Manufacturers, international lending organizations, and government agencies have also conducted numerous studies of photovoltaic pumping. Numerous combinations of a photovoltaic power supply, a pump, motor, and controls -- a basic PV powered pumping system -- have been studied, tested, and used throughout the world for several years. There are adequate amounts of credible data and reliably manufactured systems to permit consideration of PV powered pumping as one means of delivering water for irrigation.

The drawback of PV powered irrigation systems has been their high initial cost -- often double or more that of a comparable diesel powered system. Their main attributes were simplicity and low operation and maintenance costs. They have most often been used where solar radiation is at least 4 kilowatt hours per square meter per day, where the smallest commercially available diesel (approximately 2.5 kilowatts) was too large for the head and water demand conditions, and/or where fuel supply was unreliable. It has always been expected that total system costs would fall due to technology breakthroughs in PV manufacturing and the realization of savings through economies of scale associated with higher manufacturing levels.

Current Status

Today's manufacturers and system assemblers recognized as being capable of offering reliable photovoltaic powered pumping systems produce standard (off-the-shelf) systems ranging in delivery capacity from 20 to 100 cubic meters of water per day. These systems are designed to handle total dynamic heads of between 3 to 30 meters. This size range limits irrigation coverage to between one and two hectares for most crops. The systems range in cost from $8,000 U.S. to $25,000 U.S. installed.

Recognized suppliers include United States, German, French, Brazilian, and Japanese companies.

Various studies have shown that, when compared to wind and diesel powered pumping systems, those having photovoltaic power supplies are most economical for very low head and low water demand conditions. Where the product of the total system dynamic head (meters) and the water demand (cubic meters) expressed as meters to the fourth power (M^4) is less than 200 and the average solar radiation is equal to or exceeds 5 kilowatt hours per square meter per day (a sub-Saharan or tropical climate), PV powered pumps can be economically competitive with efficient diesel and wind powered systems. If the actual cost of diesel fuel is used in economic comparisons (the fuel price plus the cost to transport the fuel to the user), the range of competitiveness of photovoltaic pumping systems would increase.

In the lower ranges of head and demand, hand powered pumps become economically competitive. At present, PV pumps for general purpose irrigation are more economical than alternatives in a narrow range of flow and head conditions. The dimensions of this range of competitiveness are also affected by local and national variables. There are some specialized photovoltaic powered systems, such as those designed for use with drip irrigation piping, which are competitive with similar diesel powered systems at particular head-flow combinations.

The specific cost competitiveness of individual systems and power supplies is highly dependent on the following factors:

- Daily and seasonal crop watering requirements
- Peak instantaneous demand for water
- Solar regime
- Cost of repair and maintenance
- Total cost of PV modules

- System design
- Availability and cost of money

Detailed performance and cost comparisons based on average or typical conditions and numerous assumptions are not very useful. Competitiveness is greatly influenced by site- and use-specific details and current costs.

It is necessary to know the total system dynamic head, daily water demand, and solar radiation in order to select a pump-motor combination and to size the photovoltaic power supply. Because the PV power supply frequently accounts for more than 50% of the total system costs, small sizing changes can result in substantial system cost differences. Examination of performance data on past and currently operating photovoltaic pumping systems has revealed the following:

- To be competitive, PV systems must be accurately sized.
- A number of manufacturers and suppliers can be relied upon to deliver what they have promised.
- System failures today are most often the result of improper sizing, faulty installation, or poor operation and maintenance.
- Operation and maintenance of PV pumping systems require no more, or even less, technical knowledge than for diesel powered systems.
- Low head trough or drip irrigation applications are most favorable for PV.
- Sprinkler or flood irrigation practices are not appropriate for photovoltaic powered systems.
- Irrigation practices that involve application of smaller quantities of water over longer daily periods improve the economic competitiveness of PV systems.

The Future

The entry into the market of more component manufacturers and systems suppliers; the increase in experience with installation, operation, and maintenance; and the expected (hoped for) cost decreases in photovoltaic through the introduction of new manufacturing processes will make PV pumping systems more competitive. The introduction of efficient amorphous silicon based PV technology will take at least two years; and until the transformation from crystalline based PV is made, no major technology cost savings can be expected. As developing countries begin to manufacture PV modules, negative foreign exchange impacts will also be diminished. The cost of other fuels, especially diesel, can be expected to increase, and thus comparisons with diesel based systems will improve.

It is reasonable to expect that in the near term (within five years) photovoltaic powered systems will be economically competitive over a wider geographic area (i.e., where there is less solar radiation and water tables are lower). During this time their competitiveness will also expand to cover a much wider range of water demands. The specific dimensions of the expanded competitiveness of PV pumping systems are difficult to define, but they will be proportional to decreases in the cost of PVs between now and then. In any project where technology selection and procurement are two to three years away, solar requirements are good (± 20° latitude), and fuel costs are high, PV pumping should be considered.

At present, PVs are technologically competitive with alternative pumping systems regardless of head and water requirements, provided insolation is adequate. The deciding factor then becomes economic competitiveness under different pumping conditions. Hand pumps will continue to be competitive in lower head water demand areas, diesels will be in the higher flow and head ranges, and wind will be an equal competitor where the wind regime is acceptable. As central grid electrification programs bring electricity to rural areas and if supply is reliable, this type of pumping will also become a generic competitor. However, if true electricity costs and reliability are considered, the competitiveness of the grid connected systems would be less.

Wind pumping systems are undergoing similar and almost as dramatic improvements in technology, and their competitiveness is expected to increase. As larger wind machines improve in efficiency and reliability and as manufacturing costs decrease, it appears that wind powered machines will be formidable competitors with both diesel and PV for larger water demands. This competitiveness is, however, very dependent on the nature of specific wind regimes.

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