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# Systems for the Implementation of Renewable Energies

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### 1. General Statement of the Problem

Several of the renewable energy resources share common characteristics. They may be intermittent and, when available, are of varying and unpredictable intensity. Solar energy shows these two characteristics most strongly. Wind and wave energy are better characterized as being varying and unpredictable.

The energy systems which we have come to require either deliver energy continuously and at a constant level or provide energy on demand at a required level. There is thus an inherent mismatch between the characteristics of solar and wind energy and the requirements of current energy systems. As a consequence, the scale of future use of these renewable energy resources will depend as much on whether we find ways to resolve this system mismatch as on the technical innovations in, for example, photovoltaic technology, one of the main topics of this workshop. The mismatch problem will apply as much to any future innovational variants as it does to current technologies.

It can be addressed in terms of four almost equivalent questions:

- How can we best use the energy provided by a renewable source?
- How can that energy be matched in quality and character to the end use?
- How must we change the source or the end use to achieve optimal matching?
- Can renewable sources be linked or

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matched to conventional energy systems?

The answers to these questions would describe an energy system in which renewable energy sources are optimally matched to energy use and demand.

**2. Implementation of Photovoltaic Energy**

Because so much of the discussion at the Charmey workshop concentrated on developments of photovoltaic systems, the discussion on systems focused largely on this topic. There are three distinct areas of applications of photovoltaics:
- high-value special end uses (e.g., hand calculators, navigational buoys);
- successful integration of photovoltaic energy into existing systems;
- dispersed energy systems generally in remote rural areas of developing countries.

*High-value special applications* are being developed commercially today. Private enterprise will identify and develop other new applications. This activity will provide much of the drive and the resources for developing improved photovoltaic cells and improved special purpose systems.

*Integration into existing systems:* Electrical grids are the dominant system for the implementation and use of electrical energy. Every user of electrical energy is connected to a diffuse web of electrical interconnections. Power is delivered to this network by a number of central generating stations. A user can draw at will from the system. Because these systems use large central energy sources and require a centralized uniformity of standards for their effective management, they are generally described as «centralized» systems. This term is, in part, a misnomer. Any grid has many independent generating stations. If one or more of these stations is out of service, the system is designed so that the power demands on the system can be supplied by the other generating stations. In a wider sense of the word then, electrical grids are *decentralized* sources of supply since they are not dependent on one single source. This redundancy gives, in well designed systems, a high degree of security of supply. It supplies (and, indeed, requires) a high quality product – voltage stability and phase stability, freedom from harmonics, etc. The discussion group identified the «AC house» as a focus of the problems of integrating photovoltaics with the electric grid. This house is connected to the grid at 110 or 220 V AC (whatever is the local standard) and it uses appliances and lighting systems operating at this voltage. Depending on whether or not high-power appliances (stoves, clothes dryers) are operated electrically, the house has a peak load of between 1 and 10 kW. The house has a set of photovoltaic cells generating, say 24 V DC which is converted to 110/220 V AC for use in the house. When the house does not need the power it is fed back into the grid. As already noted the grid provides a high-quality product in terms of voltage and phase stability. As a consequence the «AC house» must have reliable high-performance power conditioning systems converting DC to AC which match the specifications of the grid. Without them «photovoltaic electricity» is unacceptable. Development of these conditioning devices is a major topic for research and development.

Considering the *economics of integration*, let us say the homeowner makes a capital investment in PV collectors and conditioning equipment. The return on this investment is seen by him as the electricity he does not have to buy from the utility. How much is it worth? The utility on the other hand sees a reduced load. It will reduce their fuel costs. Under certain circumstances it could also reduce the capacity the utility has to build into the system to provide peak power. Howe much is this worth to the utility?

This is the crux of the economic problem. A Canadian utility finds its peak loads on a winter evening in December. Photovoltaic supply would not reduce the capital investment required to provide that peak capacity. Utilities in the Southern USA may have however a peak load (due to air-conditioning requirements) on midsummer days. Photovoltaic supply could reduce these peak loads.

In general, then, the value of PV electricity to the utility which is largely in fuel costs, is likely to be significantly less than the cost of electricity charged to the consumer which has to include both fuel costs and the capital costs of peak capacity. This gap can be large and thus a major disincentive to the homeowner contemplating the investment.

Thus, the implementation of photovoltaic energy on a large scale (say 5 to 10% of the total utility capacity) requires both the provision of low-cost reliable conditioning equipment and also a careful reexamination of the peak-load problems of electrical utilities. Both of these should be major topics for R&D, albeit R&D of a very different type than that discussed at this workshop.

This problem has been studied in detail for wind systems. As noted by *M. S. Chappell*, the wind systems do not generally earn any capacity credit. Nevertheless, as seen in the California example, there are specific areas where, for a number of reasons (often non-technical), wind systems can be successfully integrated into a grid system.

*Dispersed energy systems:* The discussion group identified, as an example, the «DC house» which takes 24 V DC from the PV supply, stores direct current in a battery or some other system and uses only 24 V DC appliances and lights. It is independent of the grid. Small households in rural communities and communities in undeveloped countries, would be an example of this application.

Because it is independent of the grid the «DC house» *must have* reliable efficient high-performance storage (batteries or other storage systems). If electrical storage batteries are used they must be able to operate on deep discharge and recharge cycles. Experience has shown that while the lead-acid battery is a highly developed and reliable supply in the fully charged condition (as used in an automobile) it is often the least reliable part of the PV systems deployed in developing countries. Reliability, coupled with capital cost are thus key targets for R&D.

The «wind/diesel» hybrid is a special case. In many remote communities (Canadian Arctic communities are an excellent example), electricity is supplied to a small community by small diesel-electric sets. Diesel fuel may be flown in for distances of 1000 km or more or brought in by an annual supply boat, both at high cost. A wind generator acts as a fuel saver: energy storage is provided by the fuel storage tank. The economics for a wind system are favourable since the fuel costs for electricity are high. The system does however put a high premium on the reliability of the wind system. If the wind system fails and men or equipment have to be brought in for repair, the economics can, quickly, become disastrous. As noted by *Chappell*, reliability of wind systems is a key to their widespread adoption and a major topic for R&D.

**3. Some Environmental Considerations**

Many photovoltaic material includes toxic, heavy elements (e.g., gallium and arsenic). PV cells using these materials are, of

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course, rigourously sealed and well protected from dispersal into the environment. A large usage of such PV cells would involve the widely dispersed disposal of a large inventory of these permanently toxic materials. There could be long-term waste management problems with old decommissioned or faulty cells. Biodegradable and/or inherently non-toxic PV materials, as discussed at the workshop, would obviate this problem.

There is a paradox here. With the grid systems environmental problems are concentrated at the central generating systems. With decentralized systems of the type envisaged above, environmental problems are diffused and decentralized. It is idle to try and argue which is worse.

## 4. The Need for Research

These topics for research, power conditioning, storage, and above all reliability, are neither new nor revolutionary. The problems have been described many times. Solutions must, however, be found if we want to implement renewable energy systems on a wider scale in both the near and the far future. Without solutions to these technical system problems we may *never* be able to use any of the revolutionary ideas suggested at the Charmey workshop.

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