archive

THE ECONOMICS AND REGULATION OF USER-OWNED PHOTOVOLTAIC SYSTEMS: A PRELIMINARY ANALYSIS

Paul Carpenter and Gerald Taylor

MIT ENERGY LAB WORKING PAPER No. MIT-EL-77-030WP

September 1977

Solar photovoltaics has been considered for several years to be a leading candidate in the crusade to find a renewable-resource alternative to fossil fuels. In the few years since the Energy Research and Development Administration has directly promoted the development of the technology, considerable strides have been made toward reducing the costs of photovoltaics, thus increasing its attractiveness relative to other energy sources. Nevertheless, costs must still fall 20 to 40 fold before it can directly compete with the present exhaustable energy sources. The singular goal of the federal government R&D efforts, as a result, is to drive down the cost of photovoltaic cells by promoting the development of a mass-production photovoltaic industry. It is hypothesized that the creation of a demand for photovoltaics will provide an automatic stimulus to the supply industry. Since the present cost of photovoltaic cells requires government subsidy for any application other than those that are remote, such as satellites, ocean buoys, etc., the question of where the demand for PV will exist between now and the time when cost becomes competitive is largely a question of government policy. The cost of conventional energy supply is, of course, different for different types of applications. As a consequence, the relative economic value of photovoltaic energy will vary from one application to another. It is the premise of this paper that the governmental policy decision with regard to where the demand for photovoltaics is to be stimulated is vital to the future economic merit of photovoltaics as an alternative source of electric energy. The purpose of this paper is to discuss the issues behind potential applications of photovoltaics. The appropriateness of photovoltaics to the economic structure of public utilities will be assessed, the current emphasis of the ERDA Photovoltaics program will be described and an alternative application which might merit further investigation will be suggested. Finally, a plan of proposed research by the authors will be presented.

The economics of conventional power generation has until the very recent past mandated a non-competitive approach to electricity delivery systems. Early attempts to provide electric power on a competitive basis inevitably led to consolidation of companies within a service area or to collusive divisions of the market. The regulated monopoly came to be seen as the most advantageous method of providing reasonably priced power.

There are two economic bases which underpin the validity of the public utility scheme as we know it today. The first is the simple fact that duplication of transmission and distribution lines is a wasteful proposition. Lines and equipment for transmission and distribution represent a major portion of the cost of providing electricity, and naturally it is more efficient to avoid the parallel installations that occur when two companies try to service the same area. The second basis for today's monopoly approach is the fact that electrical power producers have in the past enjoyed declining marginal costs. There were two factors involved here. First, since a large percentage of a utility company's costs are fixed, increases in production levels up to a company's capacity (or near it) resulted in decreased unit costs. Second, there were economies of scale in conventional production. Technologies for producing large amounts of power could be installed at a price which yielded lower unit power costs than those resulting from technologies producing smaller amounts. Thus, because duplication could be avoided and economies of scale could be realized, utilities were recognized as natural monopolies. Utility monopolies, as long as their profits were properly regulated, could meet the power needs of society at minimum costs.

Present trends are changing this traditional view of electric utility economics. Rapidly increasing capital and construction costs are diminishing the gains available from scaling up capacity. Skyrocketing fossil fuel prices have inflated operating costs and electric bills. Increasing concern over the environmental impacts of fossil and nuclear fuels raises questions about the true social cost of present methods of power production. The national security value of conserving fossil fuels causes another alteration of circumstances.

Further doubt about the traditional view has resulted from the emergence of renewable resource technologies which are attractive because of their very positive environmental and fossil fuel conservation characteristics. Photovoltaic systems, for example, are very modular: they produce small amounts of power as efficiently as they do large amounts. Thus, they offer few if any economies of scale, and there is little or no advantage in aggregating units. Since photovoltaic devices are so modular, generating capacity can easily be installed where the load is located. Such load center applications preclude the necessity for transmission systems for locally generated power. Thus, the two principal pillars of the regulated monopoly approach to energy delivery systems, distribution and scale economies, may become dated by emerging technologies which offer efficient on-site electrical power generation.

There are several alternative configurations of photovoltaic systems for the generation of power as substitutes for or as additions to electric utility systems. In the initial stages of its research and development program, ERDA let three major contracts to study possible photovoltaic conceptual designs. While each of the contractors, General Electric, Westinghouse and Aerospace Corporation, identified three design types - residential, independent load centers (shopping centers, industrial parks, etc.) and central power applications - the evaluation of the economics of each application was performed from the perspective of their "value" to the utility. As a result, there was a built-in tendency to avoid the possible advantages of residential ownership of photovoltaic-utility interactive systems.

Despite the focus of the conceptual design studies, it is not clear that the central power application of photovoltaics is the most efficient of the possible alternatives. The fact that PV generators are sunlight-dependant creates problems for utilities concerned with system reliability. Only now are system planners able to evaluate the contribution a PV plant could make in a total utility system. Studies by General Electric[1] and Westinghouse[2] have resulted in evaluation methodologies which demonstrate the "effective capacity" of a photovoltaic unit, that is, the real value of a PV plant to the utility in terms of capacity, to be reduced by its quasi-random nature to a small fraction of its rated output. The complexity of the methodology itself, in its attempt to compare photovoltaics to conventional generation, belies the intrinsic difference between the methods of power generation. It is necessary to "force-fit" photovoltaics into the current generation mix through complex stochastic simulation techniques in order to compare them on similar economic grounds. Furthermore, use of PV as central generation wastes possible savings in transmission costs resulting from on-site configurations.

ERDA has recently postponed the near-term construction of planned residential demonstration projects, replacing them with larger load-center and central utility demonstrations. These developments have sparked public criticism, most notably the article by Hammond and Metz in Science which argues that "one consequence of this R&D emphasis on large-scale, long-range systems is to distort economic and policy assessments of solar energy based on the current program, both within the Energy Research and Development Administration and in higher levels of the government."[3] This criticism may be justified in that none of the conceptual design studies, and no other study to date, has evaluated the economics of user-owned, on-site photovoltaic systems.

If a market is singled out for emphasis which is inappropriate for photovoltaics both historically and economically, then larger government subsidies and more regulatory constraints will be required than otherwise would be necessary. The country would be paying more than is necessary to achieve its conservation and security goals. Recognizing the potential costliness in the current approach, we should be convinced that there are not other application alternatives more appropriate to the modular, time dependent nature of photovoltaics.

The discussion above has indicated that photovoltaic power generation is somewhat at odds with the historical regulated monopoly structure of public utilities. The characteristics of photovoltaic systems give them a comparative advantage in small, on-site applications. Residential applications appear particularly promising for several reasons. First, they take full advantage of photovoltaic modularity. Residential systems of 7KW, according to the Office of Technology Assessment[4], produce power nearly as cheaply on a unit cost basis as do 200 MW systems. There are no transmission losses since the photovoltaic output is used right where it is generated. Second, maintenance on a small scale is a simple problem compared to those faced by utility companies contemplating central power applications in the 200MW range. Module failures, difficult to detect and even more difficult to locate in several square miles of arrays, are readily apparent on a roof top scale. Washing arrays, which may become a major concern for utility companies, requiring expensive equipment and a great deal of time in presently conceived utility installations, is reduced to a homeowner hosing down the roof in a residential system. Third, the economics of residential ownership of photovoltaic equipment are very different from those which confront the utility company. The homeowner financing a photovoltaic system along with a home purchase mortgage faces a lower interest rate and hence cost of capital than does a utility company[5]. The homeowner need not pay dividends nor offer rates sufficient to compete for risk capital. Nor must the mortgagor/homeowner worry about payback periods so long as the life cycle cost of the photovoltaic system is positive. Similarly the discount rate of the homeowner (which is arguably the mortgage interest rate[6]) is much lower than that faced by the utility. Because of the differences in

capital costs photovoltaic systems may be economic from the homeowners point of view some time before the utilities would consider them a sound investment. An additional factor worth noting is that the user-owned residential unit benefits the utility company in the same manner as do utility-owned photovoltaic plants. TheGeneral Electric study recently completed for the Electric Power Research Institute demonstrated that photovoltaic generation does in fact displace conventional generating capacity[7]. A utility serving an area with substantial photovoltaic penetration would not have to maintain so large a capital investment in generating equipment as it would without the solar electric contribution. The fuel savings recognized in the G.E. study would, of course, continue to accrue to the utility irregardless of ownership. Home ownership could, in fact, maximize benefits realized by utility companies from photovoltaic generation for the simple reason that it provides the strongest incentives to the consumer to modify consumption patterns to match photovoltaic output[8]. This could provide the utilities with peak shaving benefits they could only gain otherwise by marginal cost or time of day rates.

The philosophy underlying the National Energy Plan is that energy conservation will reduce national dependence upon foreign oil and help to insure against the economic dislocation which would result from a severe scarcity of fossil fuels. Certainly this same conservation philosophy is at the root of present programs to develop renewable energy technologies. It follows directly, then, that if the country is willing to pay a positive premium to develop energy independence and allay economic dislocation, then programs should aim to minimize that premium, or conversely, to maximize the conservation value of dollars spent. Within a narrowly defined program such as the Photovoltaics Program at ERDA this concept clearly requires careful decisions as to where program funds should be spent to maximize impact. Consideration must be given to all likely development alternatives. Given the apparent advantages of residential, user-owned photovoltaic applications, it would seem prudent to fully investigate such applications before reaching a final decision on a long term development plan.

On the following pages is the preliminary outline of a proposed effort to investigate the economic and regulatory issues involved with the on-site application of solar photovoltaics. It is proposed that this task be approached from a utility-specific, case-study perspective, in order to attempt to uncover some of the key variations in the results by region.

0. Intro & Initial Hypotheses

I. Selection of Regions & Utility Companies
   A. Regional Analysis
      1. Methodology
      2. Regions
   B. Utility Selection
      1. Generation mix
      2. Load Profiles
      3. Data availability
         a. Utility information
         b. Quality of insolation data

II. Residential Simulation
   A. Methodology - Tatum Model
      1. Model description
      2. Data inputs
         a. System configurations
            (1) Array size
            (2) Storage
         b. Rate structure
         c. Consumption
            (1) Appliance ratings & use patterns
            (2) Behavioral assumptions
      3. Sensitivity Analysis

III. Life Cycle Costing
   A. Methodology
      1. Operating costs - Tatum Model
      2. Capital costs - SAMICS model
      3. Maintenance Costs - FIOM
      4. Degradation & Failure Comment - Assumptions
      5. Taxation assumptions
      6. Other necessary assumptions - Justification

   B. Results
      1. Regional Life Cycle Costs for optimized system
      2. Comparisons to base case
      3. Sensitivity Analysis implications
   C. Policy Assessment
      1. Duration & Magnitude of subsidies necessary, if any
      2. Penetration implications of various policy scenarios

IV. Utility Impacts
   A. Technical considerations
   B. Penetration scenarios
   C. Interface simulations
      1. Methodology
         a. Total cost approach
         b. Model description
         c. Assumptions and base case description
      2. Inputs
         a. Utility data
         b. Residential load-Tatum Model Output

D. Simulation Results
   1. Presentation
   2. Sensitivity Analysis
   3. Economic analysis & implications for utilities- Comparison with central power studies done to date
E. Regulatory implications and scenarios

V. Comparison of Results with Initial Hypotheses

VI. Policy Assessment - Comparison of residential sector applications to other possible funding alternatives

A. ERDA and National energy goals
B. Generalization of methodology to other onsite renewable resource technologies

FOOTNOTES

1 "Requirements Assessment of Photovoltaic Electric Power Systems" under taken by General Electric Company for the Electric Power Research Institute, Palo Alto, California, contract RP651-1

2 "Utility System Reliability Assessment Techniques" a Westinghouse Electric Company follow on project under ERDA Contract E(11-1)-2744, "Conceptual Design and Systems Analysis of Photovoltaic Power Systems"

3 Hammond, Allen and Metz, William, "Solar Energy Research:Making Solar After the Nuclear Model", Science, Vol. 197 No. 4300, July 15, 1977.

4 "Application of Solar Technology to Today's Energy Needs", Office of Technology Assessment, Washington, D.C. (June 1977) (prepublication draft) p. I-11

5 Mortgage Interest rates are presently hovering around 9% or just below. In a recent study by MITRE Corporation "Solar Energy Applications- A Comparative Analysis to the Year 2020" July 1977 (Draft) the figures used to approximate the utility sector yielded a capital cost of 13.2%.

6 Since the most common scenario will probably be the new home purchase, the purchasers opportunity cost is reflected by the mortgage rate because the investment alternative is not to incur additional debt to pay for the photovoltaic system.

7 "Requirements Assessment of Photovoltaic Power Systems", op.cit. In each of the three utility systems covered in the study the addition of photovoltaic generating capacity increased system reliability thus allowing the retirement of some conventional generating equipment. The amount of displacement varies from utility to utility and is dependent upon the correlation between incolation and peak load, utility generation mix and other factors

8 Work with experimental rate structures such as that recently completed for Central Maine Power indicates that consumers modify their consumption patterns markedly to minimize energy bills when given the opportunity to do so. Photovoltaic systems then might prompt customers to shift consumption to take advantage of "free" solar electricity. Such behavior would be promoted by the very character of the photovoltaic systems so long as back up rates do not discourage it. Marginal cost or off peak pricing would be necessary otherwise if the utility wanted to promote conservation of centrally generated power.