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THE ROLE OF PV IN DEMAND-SIDE MANAGEMENT: POLICY AND INDUSTRY CHALLENGES

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ABSTRACT

Most electric utility planners consider photovoltaics to be a frontier technology which is not yet mature enough to contribute to the U.S. electric generation market. Over the past decade, utilities and their regulators have begun to emphasize demand-side management (DSM) to meet an increasing proportion of their service needs. For PV to be a valued technology in the electricity sector, DSM applications need to be identified that can provide a significant market for this technology. DSM programs of 20 of the most active utilities in the DSM market are analyzed in this research to determine the size, prices, demand, and impact of policy. Target PV-DSM markets are identified and the policy and industry challenges that must be met are defined.

INTRODUCTION

Photovoltaic (PV) technology can be applied to reduce peak load electricity demand in one of three ways. It can replace existing power sources, complement them, or serve as a load management device with the objective of interrupting a power load for a period of time. In its replacement and complementary roles, PV technology's peak load reduction is equal to the power it generates. To date, PV has been investigated largely in one or the other of these supply-focused roles. By being considered an electricity supply technology, PV, presently at a cost of 50 cents per kWh, is too expensive to stimulate much interest by either electric utilities or state regulatory authorities. Surveys of utilities and regulatory commissions carried out by the Center for Energy and Urban Policy Research[1,2] indicate that PV applications rank below next-generation nuclear power in importance as alternatives for meeting electricity capacity needs (Figure 1).

The low ranking of PV is explained not only by its high supply cost, but also by the recent transition in regulatory and utility environments in the electricity sector. Over the past decade, emphasis has shifted from supply planning to integrated resource planning (IRP). Virtually all utilities and three-quarters of the regulatory commissions in the U.S. surveyed by CEUPR are relying upon demand side management (DSM) programs and IRP to meet capacity needs. In fact, utilities and commissions consider DSM options more important than supply-side options in planning future capacity needs (Figure 1). PV has not been a significant participant in this transition despite the fact that the long term market prospect for this technology is generally acknowledged to be in the utility sector.[3]

For PV to play an important role in the new electricity sector environment, emphasis needs to be placed on its capacity to function as a load management technology. In this role, PV-generated power can be used to interrupt electric loads during peak operating periods for the utilities. Importantly, in this role PV averts a load which is in excess of the power output of the PV array. This is accomplished by utilizing a low but constant PV output to maintain a low level of operation of an electric device which normally operates intermittently and, in so doing, to establish an interval during which the device remains "off" in terms of grid power use.

If a load management role for PV can be demonstrated and if its economic viability in this role can be determined, it becomes possible for PV to enter an intermediate market which may prove to be vital for near- and mid-term growth of the PV industry. The research effort described in this paper has been directed towards evaluating the market opportunities for PV systems in the rapidly expanding DSM market.

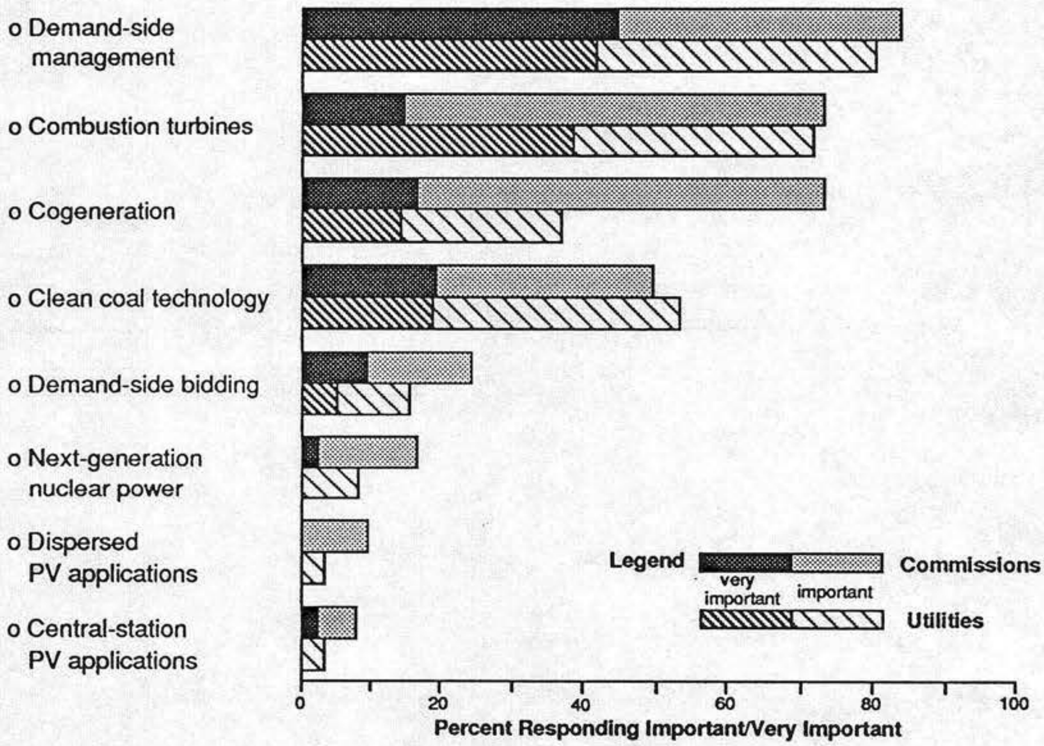

Figure 1 Alternatives for Meeting Electricity Capacity Needs

METHODOLOGY

The evaluation of the possible role of PV in demand-side management has been accomplished through the pursuit of three objectives. The first objective was to characterize the economic demand of electric utilities for DSM-supplied electricity savings. Second, an analysis of the end-use targets of the DSM market was prepared. Finally, the impact of various factors, including regulatory environment, on the DSM market was conducted. Once these objectives were met, end uses of electricity which appeared to be most attractive for the incorporation of PV technologies were selected for further analysis.

The traditional electricity market is built upon a relationship between utility companies as energy suppliers and customers as energy purchasers. The combined pressures of higher capital costs and fuel prices, growing environmental concerns and recent regulatory policy reforms have led to a transformation in this market relationship. Utility companies and their customers now operate on both sides of the meter as utilities attempt to purchase load reductions from their customers and ratepayers seek to supply energy efficiency and alternative power to their utilities. DSM rebate programs are an important part of the new relationship between utilities and customers. In the DSM market, rebates represent the prices which utilities are willing to pay customers to encourage their investment in end use efficiency. The upper limit of DSM rebates is set by the cost of buying back capacity from customers compared to generation and purchase power options available to a utility. In this market, demand is typically for kW reductions during peak periods and the offering price is equal to the rebate amount expressed in $/kW saved.

To establish whether an empirical relationship between rebate levels offered by utility DSM programs and electricity (kW) savings exists, data were collected on rebate amount levels, estimated or actual kW saved, and cost per kW saved for the most active utilities in the DSM market. To determine which end uses are the most attractive targets for utility DSM programs, and from which types of customers utilities are interested in "purchasing capacity," rebate and savings data were analyzed by sector and end-use. A statistical analysis was then performed to measure the relative effect of various factors, including regulatory climate, air quality issues, fuel mix, regional location, and size and financial position of the utilities.

Table I Study Utilities

- City of Austin, Texas *
- Atlantic City Electric *
- Boston Edison *
- Central Hudson Gas & Electric *
- Central Main Power *
- Commonwealth Electric
- Delmarva Power & Light *
- Florida Power & Light *
- Jersey Central Power & Light *
- Long Island Lighting *
- Madison Gas & Electric *
- Montana Power
- Nevada Power *
- New England Electric *
- New York State Electric & Gas *
- Niagara Mohawk
- Northeast Utilities
- Northern States Power *
- Orange & Rockland Utilities *
- Pacific Gas & Electric *
- Public Service Electric & Gas *
- Puget Power *
- Rochester Gas & Electric
- Sacramento Municipal Utility
- San Diego Gas & Electric *
- Sierra Pacific Power *
- Southern California Edison *
- Texas Utilities *
- United Illuminating
- Wisconsin Electric
- Wisconsin Public Service

* Detailed information available for DSM rebate programs of these utilities.

The analysis concentrates on 20 utilities that have the most extensive experience with DSM programs (Table I).[4] Additionally, DSM programs offered by Delmarva Power were included because of this utility's participation in the research effort. Extensive data were gathered from both primary and secondary sources. Mailed questionnaires and follow-up telephone interviews constituted the primary data sources. Several studies and surveys were used as secondary sources in order to supplement the primary data collected for this study.[1, 2, 5–15]

THE DSM MARKET IN THE UNITED STATES

The 21 utilities analyzed for this study administered 78 different rebate programs in 1991. These programs included end-uses of all types in the residential, commercial and industrial sectors (Figure 2). Over half of all residential rebate programs targeted air conditioning and water heating. Commercial and industrial programs were concentrated in lighting, air conditioning/HVAC, thermal storage, multi-conservation and motor end-uses.

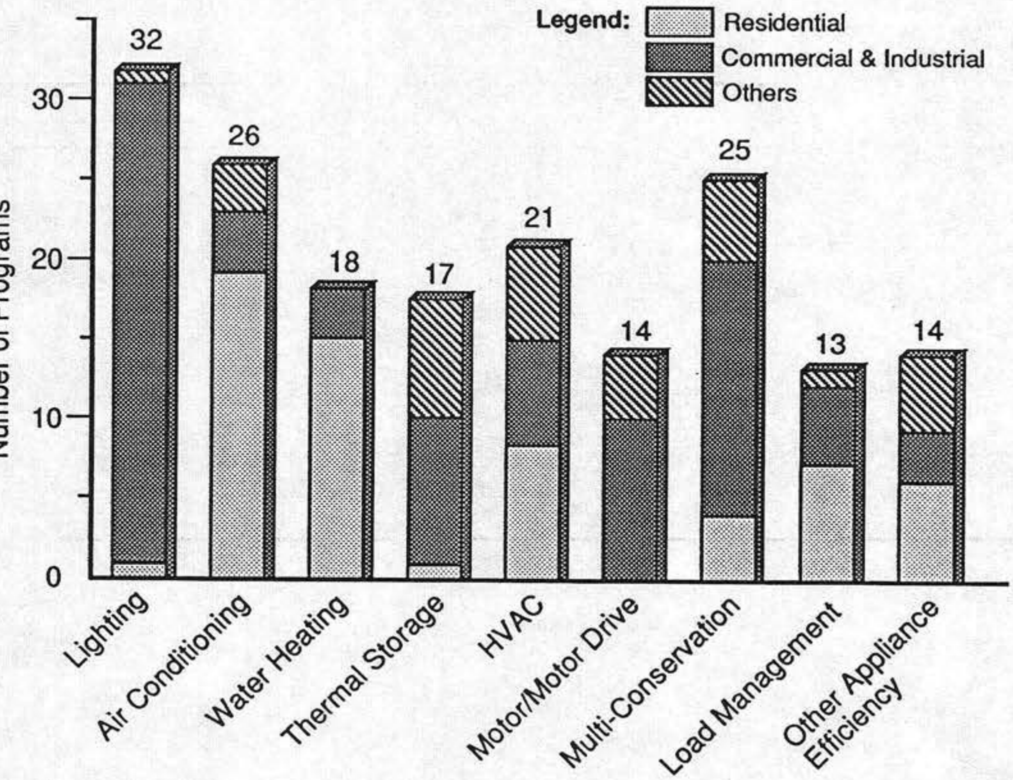

Figure 2 Number of Rebate Programs and Target Sector

The range of rebate values per kW saved was very broad, varying from \$50 per kW, to over \$800 per kW. For individual programs, the total avoided capacity also ranged widely, from ones which saved less than 100 kW to a program with a 1991 savings of 71,500 kW. Considerable variation in pricing existed for several program categories; thus, commercial HVAC rebates extended from \$75 to \$700 and residential water heating rebates varied from \$150 to \$1,500. A log-linear regression on the aggregate data yielded a demand curve of normal shape and a statistically significant parameter estimate for the rebate price variable ($t = -3.16$, $p < 0.002$) However, the proportion of the variance accounted for by the regression was low ($R^2 = 0.115$). Since the demand relationship was being initially estimated across customer classes and end uses, the low R^2 was not surprising.

A second-stage analysis was conducted to investigate the relationship between price (rebate per kW saved) and energy savings for particular end-uses and customer sectors. To ensure comparability, programs with only a few participants (typically, single-customer commercial and industrial programs) were excluded. Multi-conservation programs were also excluded because the energy savings achieved by them could not be disaggregated and attributed to particular end-uses. Finally, pilot programs were excluded because rebates offered in these cases are not based on experience and rarely reflect the prices utilities eventually will be willing to pay to achieve energy savings. After screening the data, 41 programs remained for analysis.

Next, data were summed by end-use category and customer sector within similar price ranges. This process resulted in 11 distinct program categories. A demand curve was estimated based on this data set (Figure 3) and the proportion of variance explained by the regression was reasonably good ($R^2 = 0.444$). The price elasticity of demand remained near unity ($e_p = -1.060$), indicating that utilities are price-sensitive across the range of end-uses and customer categories. As Figure 3 indicates, utility price sensitivity is especially for rebates of \$200/kW or less.

This analysis suggests that the DSM market has two distinguishable segments. One segment mainly involves lighting programs directed exclusively to the commercial and industrial sector. In this segment, relatively low rebates (\$60 - \$200) can effect the greatest energy savings. In consequence, electric utilities tend to be most willing to "buy" avoided capacity through lighting rebate offerings. The other market segment is dominated by programs aimed at reducing grid loads presented by air conditioners. Here, mostly residential and commercial customers are participants. Rebates are typically in the \$300 to \$400 per avoided kW range. Utility demand, consequently, is lower, typically in the range of 2,000 to 4,000 kW per program.

After the construction of a DSM market demand curve, a multivariate analysis was performed to estimate which variables best predicted utility demand for avoided capacity through rebate offers. The effects of utility size (expressed both in generation capacity and sales), fuel mix, financial position (whether there was surplus or deficit in the utility's net income), SO_2 emissions, regulatory environment (based on an index of DSM cost treatment in state regulation), rebate levels, and rate structure were investigated. The statistically significant predictors (as indicated by the t-statistics of the slope terms) were found to be the rebate amount (i.e., price) and regulatory environment (Table II). SO_2 emissions were the next most efficient predictor but the t-statistic for this variable indicates that this variable's predictive capacity is not statistically reliable.

The positive effect of regulatory environment on utility DSM demand was specifically traced to policies which allow DSM program costs to be capitalized.

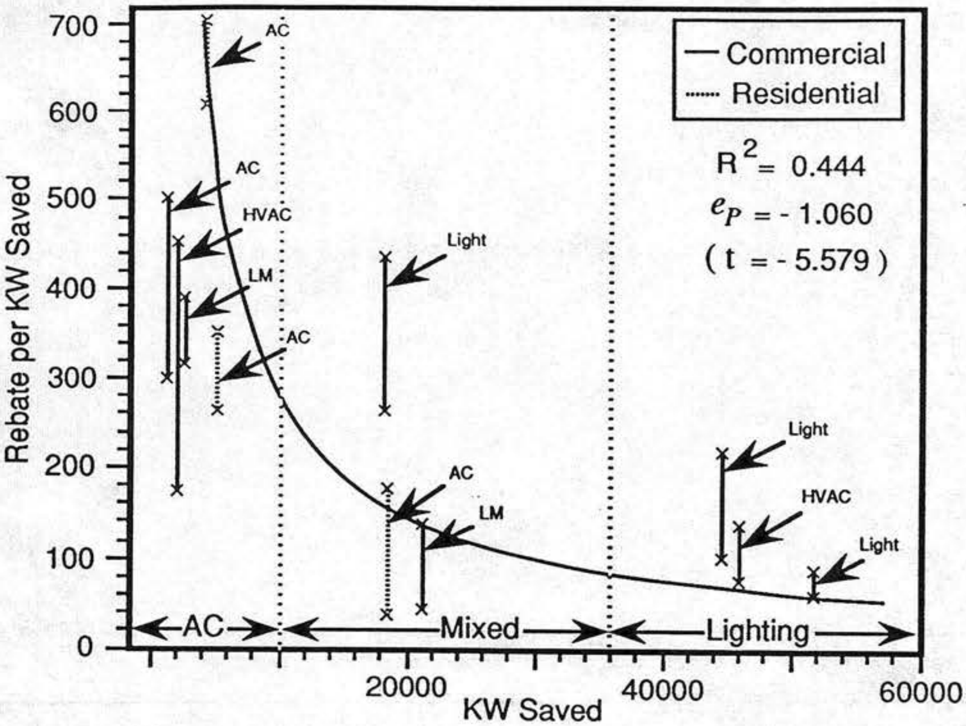

Figure 3 Demand for KW Saved by End Use for the 21 Most Active Utilities
(Grouped by Rebate Value)

Table II Influences of Rebate Amount, Environmental Issues and Regulatory Policy on Utility Demand for KW Saved

	Coefficient	T - Statistics
C	13334.89	4.248 ($p<0.000$)
REBATE	- 20.845	- 2.104 ($p<0.042$)
REGDUM	6498.396	1.865 ($p<0.070$)
SO_2	0.041	0.888 ($p<0.381$)
R^2 = 0.169		

Notes: REBATE: Rebate amount per KW saved
REGDUM: Dummy variable for regulatory Environment
(0 = less favorable; 1 = favorable)
SO_2 : SO_2 emission from electric generation

Utilities operating in areas of the country where such regulations exist are willing to "purchase" more avoided electric generation capacity in the higher rebate range.

PV AS A DSM OPTION

These findings help to identify potential markets for PV as a DSM tool. The advantage for PV in a DSM market is the favorable economics that result because the technology is credited with displacing much larger loads than the energy output rating of the installed PV panels. This advantage is available when PV is used in conjunction with electric devices which typically operate in an intermittent mode. Prime markets for this technology appear to exist in the residential sector for air conditioners and water heaters, and for air conditioners in the commercial and industrial sectors.

Both air conditioners and water heaters are devices which operate intermittently, making them technically compatible with PV used as a DSM technology. Furthermore, these end uses fall within the higher-priced range of the utility DSM demand curve. Competing with other DSM options in a market segment where utilities are willing to pay higher rebates for avoided power loads can prove to favor PV. Not only is economic feasibility greatest for this segment, but PV may provide the additional advantage of maintaining service levels above that of traditional DSM options. For example, utilities frequently rely upon direct load control strategies to interrupt or cycle grid service to residential and commercial water heating and air conditioning devices. But a PV application may offer a superior level of service during periods when grid power is interrupted or cycled by, for example, maintaining a higher water temperature or better circulating the cooled air in a building.

A preliminary estimate of the cost of a PV-assisted water heater program in the Delmarva Power & Light Company service area suggests that such a PV-DSM approach could be competitive with the present direct-load control program for water heaters, if the utility were to offer a rebate of \$3 per rated peak watt (about 50% of the cost of a PV panel) and pay the full installation cost, estimated at \$150. The levelized net present value for this PV-DSM program was estimated to be approximately \$600 per kW saved (see Table III). Although the rebate of \$300 would be in the upper range of the utility DSM demand curve, it still is within the domain of incentives currently offered by utilities, particularly in the residential sector. If the rebate could be treated as a capital investment by the utility, the economics of PV as a DSM tool could be sufficiently attractive to encourage utility interest.

CONCLUSIONS

Results of this study of the 21 most active utilities in the DSM market indicate that the highest rebates are paid for load reductions from residential and commercial air conditioning, water heating and load management programs (which usually involve the direct load control of these two electric devices). These applications offer PV its best opportunity to compete with other DSM options. An initial rough estimate of the cost of PV in one such application indicates that it would be worthwhile to explore use of the technology to interrupt water heating or air conditioning power loads during peak use periods.

Table III Illustration of PV as a DSM Application: Residential Water Heating

	WH DLC	WH PV
Program Assumptions		
Customer Incentives	$12/yr.	$300
Discount Rate	11.26%	11.26%
Inflation Rate	4.5%/yr.	4.5%/yr.
Device Costs (per unit)	$75	$300 (48 Wp panel)
Installation Costs (per unit)	$46	$150
Switch Replacement Costs (per failure)	$85	—
Switch Removal Costs (per request)	$35	—
kW Reduction Per Point	0.39 kW	0.39 kW
Participants	83,675 (28%)	83,675 (28%)
Service Interruption Period	8 hrs.	8 hrs.
Planning Period	20 yrs.	20 yrs.
WH Assumptions		
Tank Capacity	52 gal.	52 gal.
Power Rating	4.5 kW	4.5 kW
Insulation	R 12	R 12
Reference Temperature	120°F	120°F
Solar Panel and Resource Characteristics		
Power Rating	—	48 Wp
Solar Energy Input	—	1 kW/m^2 (0.67kW/m^2)
Module Efficiency	—	11-12% (15-17%)
Cost/Wp	—	$6.00

Results

	Program Size (MW)	Levelized NPV ($/kW)*
WH PV	33	$ 616
WH DLC	33	738
Gas-Fired Combustion Turbine	100	437
Coal-Fired CFB	150	1,800

* Net present values levelized over 20 years for WH PV and WH DLC options, and 30 years for the two generation options.

Source: Delmarva Power.[16]

The next step is to evaluate the possible role of PV-DSM in practical operating settings. Such a test is under way utilizing a university solar house. Results of this test are expected to be available in late 1992.

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