DOE/NASA/0040-78/1
NASA CR-159477

(NASA-CR-159477) MARKET DEFINITION STUDIES FOR PHOTOVOLTAIC HIGHWAY APPLICATIONS (Technical Marketing Associates, Inc.) 121 p HC A06/MF A01 CSCL 10A
N79-19451
Unclas
G3/44 16385

MARKET DEFINITION STUDIES FOR PHOTOVOLTAIC HIGHWAY APPLICATIONS

Technical Marketing Associates, Inc.

December 1978

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lewis Research Center
Under Contract DEN3-40

for
U.S. DEPARTMENT OF ENERGY
Office of Energy Technology
Division of Distributed Solar Technology

TABLE OF CONTENTS

I. OBJECTIVES OF THE PROGRAM

Phase I

A. To become familiar with a wide range of potential photovoltaic applications for the powering of highway-related electrical equipment operated by governments and commercial organizations.

B. To gain sufficient quantitative and qualitative information about such applications to permit screening and evaluation, including data such as:

(1) Number of existing installations.

(2) Distribution of installations by state.

(3) Typical KW electric load associated with each application, as well as character of load, i.e.: continuous, nights only, or intermittent (if so, on what basis).

(4) Economic parameters of power supplies now in use, so as to permit estimation of:

(a) Total first cost of power installation (as well as typical depreciation procedures).

(b) Annual operating and maintenance costs.

(5) Alternatives to utility power which are in use or considered for the future, and criteria for retrofitting, if any.

(6) Other criteria in power supply selection, such as legal restrictions, concern for reliability, etc.

(7) Outlook for future installations: 1978-1988.

(8) Distribution of future installations in terms of distance from existing utility power lines.

(9) Identification of leading purchasing agencies.

C. To select applications which appear to warrant investigation in greater depth, on the basis of:

(1) Immediate market potential (1979).

(2) Future market potential (1986).

(3) Visibility and promotability.

(4) Enthusiasm of users interviewed.

(5) Opinion of TMA.

Phase II

A. With respect to the application (highway signs) selected for intensive study on the basis of the findings of Phase I:

(1) To define the products and markets associated with this application, considering factors such as product specifications, pricing, market composition, market growth, distribution channels, and competition.

(2) To characterize the leading manufacturers involved in the highway sign industry.

B. With respect to broader classes of applications in selected states:

(1) To prepare materials which will quickly acquaint highway officials with the performance, essential specifications and cost of solar electric power.

(2) To discuss specific potential applications of solar electric power in detail with these state highway officials, so as to evaluate its economic attractiveness compared to alternative power sources.

(3) To encourage and assist highway officials, where appropriate, in specifying solar power.

C. With respect to both of the foregoing avenues of investigation:

(1) To analyze the basis on which photovoltaic power can compete, and, where it can, to forecast the size and growth rate of the photovoltaic market.

(2) To identify and describe the various forces which may impede the acceptance of photovoltaic power.

(3) To suggest steps by which Lewis Research Center might stimulate and accelerate the use of photovoltaic equipment.

II. METHODOLOGY

A. Interviewing Program

Much of the information used in this study was gained through interviews with government officials and representatives of corporations and associations. In particular, officials of the highway departments and other agencies of 49 states were interviewed. The State of Hawaii was excluded from the interviewing program by prior agreement with NASA. The following summarizes the interviewees by the types of organizations they belong to:

Type of Organization	Number of Interviews
State Agencies	192
Federal Agencies	12
Sign Manufacturers and Erectors	29
Manufacturers of Other Highway Equipment	21
Photovoltaic Equipment Suppliers	9
Power Companies	13
Highway Construction Contractors	6
Associations, Publications, and Other	4
Total	286

B. Library Research

To the extent possible, information derived from the interviews was supplemented by published data and reports obtained from several sources:

(1) U. S. Census of Manufactures and Current Industrial Reports.

(2) U. S. Departments of Transportation and Energy.

(3) National Institute of Science.

(4) State Agencies.

(5) Appropriate Trade Journals.

(6) Reports of Other Consultants.

III. FORMULATION OF GUIDELINES FOR INVESTIGATION

A. General Background

Essentially, this study is the investigation of a potential market (the nation's highway system) for a new product (solar electric power). In this market, the product is very little used and generally unknown. Such an assignment inherently becomes one in which it is extremely difficult to secure hard, quantitative data, or to draw conclusions which can be supported by firm facts.

To begin with, what is the term "highway market" meant to include? Clearly the market is immense, but it is ill-defined. As seen by makers of electrical equipment, the highway market certainly includes the vast complex of federal, state, county, and local governments which construct and maintain the nation's highway system. Most observers would agree that it also includes the many types of contractors who make installations and perform services for these governments. In TMA's view, the market also comprises commercial establishments of various types which are situated adjacent to highways and draw their revenues from the needs of highway travelers.

It is instantly perceived that the electric power needs of the highway market are normally provided through the supply of ordinary utility power. Even in cases where a permanent electrical installation must be made at a point which is remote from the existing utility system, it is normally the practice to provide power simply by extending the utility distribution line. Although contractors make considerable use of small engine generators, this equipment, which entails considerable expense for operation and maintenance, is generally used only for power requirements which are temporary. In a few cases, use is made of thermal-electric generators for permanent highway-related installations, but these cases are rare indeed.

In the course of the present study, solar electric power was found to be used in only a few instances for highway-related applications. Three states were found to have used solar power to operate motorist's aid call boxes; one state was operating a variable-message sign from a solar source; two additional states had solar-powered railroad crossing signals; and at least one installation was described for a solar-powered bridge corrosion protection system. Nevertheless, most states were acquainted with solar power only to the extent of having read occasional articles on the subject in the press. For most highway officials, therefore, solar electric power was essentially an unknown.

The solar electric power industry, for its part, was found to have taken very little interest in highway-related applications. Practically all commercially viable solar electric power installations in the United States were found to center on applications of only a few types: power for off-shore navigation lights; power for communications relay stations located on mountaintops; cathodic protection systems for pipelines in remote areas; and, to a lesser extent, power for railroad signaling systems. Little or no consideration had been given to power requirements related to highways.

B. Costs of Photovoltaic Power

Under these circumstances, it was felt necessary to direct the investigation toward areas of application where solar power could show economic advantages compared to other power sources. As a starting point, therefore, TMA adopted conventions proposed by NASA for comparing the total cost of solar electric power with that of utility power. In this method, comparisons were made on the basis of equivalent present value of total system cost, taking into account both first cost and projected operating and maintenance cost over a 20-year life. Further to facilitate comparison with other estimates prepared by NASA and DOE, figures are deflated to a "1975 basis."

The assumptions used for estimating the 1975 equivalent total cost of a solar electric power system are summarized in Exhibit 1. While many variables figure in the cost of a photovoltaic system, the most significant ones are seen to be the size of the equivalent continuous electrical load which the power supply must serve, the climatic conditions in the location where the installation is to be made, and the market price of solar electric generating equipment. This last factor is expected to change considerably as time progresses. Although the small-quantity cost of photovoltaic modules at the time of this investigation was found to run between $10 and $15 per peak watt, these prices have been falling at an encouraging rate, and the Department of Energy has established a target price of $.50 per peak watt for the mid-1980s. Consequently, TMA has sought to use methods of cost comparison which allow for possible changes in each of these variables.

C. Costs for Extension of Utility Power

When the utility power distribution system is to be extended in order to serve an installation related to a highway, it is generally necessary to pay the utility a fee to cover the cost of erecting additional utility poles, as well as wire and fittings for the new power line. It is difficult to predict the cost of a power line extension, since this cost depends not only upon the length of the extension, but upon the terrain over which it must be erected, and the pricing policies of the utility itself. Many utilities appear deliberately to minimize charges for power line extension, probably because it has been their traditional practice to do everything possible to encourage the enlargement of their connected load structure. Nevertheless, utility philosophy varies greatly in this respect, and it is not unusual to find dozens of different utility fee policies in effect within the confines of a single state.

As a rough rule of thumb, TMA has adopted the assumption that utility power line extensions will cost the highway user approximately $3 per foot in 1978 dollars, or $2.66 in 1975 dollars. Actually, the figure of $3 per foot appears to be somewhat higher than is typical of the majority of utilities contacted by TMA during this investigation, as can be seen by reference to Exhibit 2. In any event, the minimum size of power line installed for such a cost will have more than enough current capacity to serve a load of any size for which photovoltaic power is likely to be competitive.

D. Rough Comparison of Photovoltaic vs. Utility Power Cost

Mathematical application of the assumptions described above permits a comparison of the total 1975 costs of solar electric power with those of utility power. Such a comparison can be made graphically through the use of Exhibit 3, which applies only to sections of the United States where the climate would be favorable to a photovoltaic system. On this exhibit, the ordinate is total system cost in 1975 dollars, displayed on a logarithmic scale. The abscissa is the equivalent continuous electric load to be driven in watts, also on a logarithmic scale. The exhibit presents two sets of curves. One set of curves, drawn with solid lines, describes the total cost of photovoltaic power based on three assumed prices for photovoltaic modules: $11 per peak watt (which approximates the best pricing currently available for small-quantity purchases); $.50 per peak watt (which represents DOE's target price for the 1980s); and an intermediate figure of $5 per peak watt. Since the cost of a solar electric power system increases nearly in direct proportion to its wattage capacity, these curves slant upward toward the upper-right-hand corner of the exhibit.

The other set of curves on the exhibit, represented by dashed lines, describes the total cost of using utility power. The curves are drawn for three representative distances of power line extension: one-half mile, one mile, and two miles. Because most of the cost of the utility power alternative is the cost of extending the power line, these curves are essentially flat, although, as the wattage load increases, the future cost of the power consumed produces a slight upward curvature.

The intersections of these two sets of curves facilitate comparison of the costs of solar electric power and utility power. For example, if the driven load is assumed to consume 60 watts on the average, and photovoltaic modules are assumed to sell at $11 per peak watt, the curve shows that photovoltaic power enjoys an advantage in total cost as long as the installation is to be made at a location which would require extension of the power line by 0.95 miles or more.

As a by-product, this exhibit also illustrates that a considerable reduction in the cost of photovoltaic modules will have surprisingly little effect on this cost comparison. In the instance just cited, for example, if the cost of photovoltaic modules were to fall all the way to $.50 per peak watt, the breakeven distance for power line extension would diminish only to 0.70 miles.

The comparisons in Exhibit 3 would apply only in portions of the United States where climatic conditions are such that a solar electric power installation will require a peak wattage rating 5.5 times as great as that of the equivalent continuous wattage consumed. Exhibit 4 shows a similar comparison made for a zone in which the peak/average wattage ratio is 8.0, and Exhibit 5 shows a third comparison for relatively unfavorable areas in which the ratio is 10.5.

Exhibit 6 is a map of the United States indicating the approximate areas in which these various wattage ratios would normally be applicable. Geography also turns out to have a surprisingly small effect on the comparative cost of solar electric power. Consider, for example, the continuous 60 watt load mentioned above, with photovoltaic cell pricing at $11 per peak watt. As one moves from a favorable climate (Exhibit 3) to an unfavorable one (Exhibit 5) the "breakeven" distance for power line extension only increases from 0.95 miles to 1.30 miles.

A study of the comparisons shown in Exhibits 3, 4, and 5 permits certain generalizations to be made:

(1) Solar electric power is unlikely to be an attractive alternative to the extension of utility power in cases where average served load is greater than 100 watts.

(2) Solar electric power is unlikely to be an attractive alternative to utility power in cases where the load can be located a distance of less than one-half mile from an existing power line.

Consequently, as a first approximation, TMA assumed that its investigation of highway-related opportunities for solar electric power should be confined to applications in which the equivalent continuous load is no more than 100 watts, and where the proposed installation was to be made at a spot located at least one-half mile from the nearest utility power.

With these criteria as a guide, TMA's investigation then turned to the examination of actual highway applications.

Exhibit 1

ASSUMPTIONS USED IN COST COMPARISONS OF PHOTOVOLTAIC VS. UTILITY POWER

1. General

(a) Power systems have a lifetime of 20 years, with no salvage value and no charges for disconnection or dismantling at the end of that lifetime.

(b) The discount rate is 8%.

(c) Any annual maintenance costs on either type of power system can be neglected.

2. Photovoltaic Power

(a) The cost of the "balance of the system," excluding the solar cell array and the batteries, is $1,000 plus $5 per peak watt.

(b) The cost of the batteries is $70 per Kwh of nameplate rating.

(c) Batteries are replaced every five years.

(d) Battery capacity is chosen to give six days of storage within a design depth of discharge of 25% (because of high reliability requirements).

(e) The ambient temperature has no effect on battery capacity or solar cell efficiency.

(f) The round-trip efficiency of the batteries is 75%.

(g) The time from sunrise to sunset each day is ten hours.

3. Utility Power

(a) The cost of extending a single-phase, overhead, primary distribution line under ideal soil and terrain conditions is $2.66 per foot (in 1975 dollars) less either the cost for 400 feet or 3.5 times estimated annual revenue, whichever results in the lowest total cost.

(b) The cost of electricity is taken from the table below, which is based on a small sample of rates for commercial and government customers on power use by customer-owned and maintained equipment and which is corrected to 1975 dollars.

24-Hour Average Demand (Watts)	Annual Electricity Cost
10	$ 34.92
20	37.26
40	42.91
80	59.16
100	67.13
200	109.62
400	193.38
800	358.49
1000	438.47

(c) The customer makes only one payment for electricity use each year.

Sources: NASA; TMA

Exhibit 2

EXAMPLES OF CHARGES FOR EXTENSION OF COMMERCIAL POWER LINES

Power Company	Minimum Charge For Power Line Extension*	Est. Annual Energy Charge For Average Load of: 10W	100W
1. Boston Edison Co. Boston, Massachusetts	$4,880	$39	$111
2. Central Maine Power Co. Augusta, Maine	$6,420	$70	$102
3. Florida Power and Light Company Miami, Florida	$4,480	$ 5	$ 44
4. Houston Lighting and Power Company Houston, Texas	$1,920	$38	$ 76
5. Nashville Electric Service Nashville, Tennessee	$6,197	$36	$ 36
6. Niagara Mohawk Power Corporation Syracuse, New York	$4,922	$45	$ 87
7. Pacific Gas and Electric Company San Francisco, California	$7,775 (10W) $7,500 (100W)	$107	$159
8. Puget Sound Power and Light Co. Bellevue, Washington	$16,465 (10W) $16,365 (100W)	$44	$ 64
9. Union Electric Co. St. Louis, Missouri	$ 161 (10W) $ 83 (100W)	$52	$ 78
10. Virginia Electric and Power Company Richmond, Virginia	$2,605 (10W) $2,304 (100W)	$ 5	$ 48
11. Wisconsin Electric Power Company Milwaukee, Wisconsin	$3,410	$70	$103

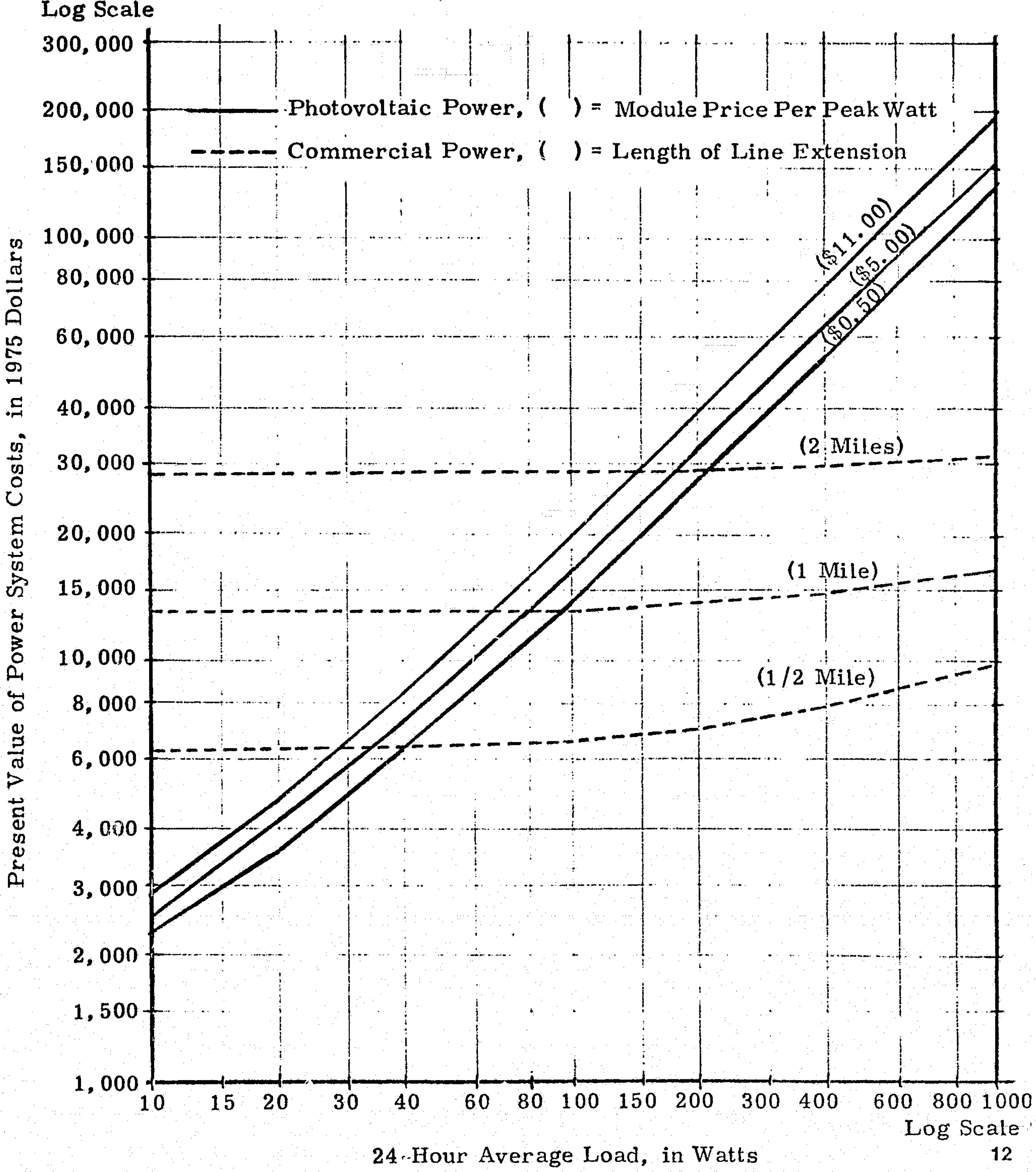
*On the basis of a half-mile extension of single-phase, overhead, primary distribution line with meter set and transformer, under ideal soil and terrain conditions.

Source: TMA

Exhibit 3

COST COMPARISON: PHOTOVOLTAIC VS. COMMERCIAL POWER

(Based on Assumptions Detailed in a Previous Exhibit)
P/A = 5.5



Sources: NASA; TMA

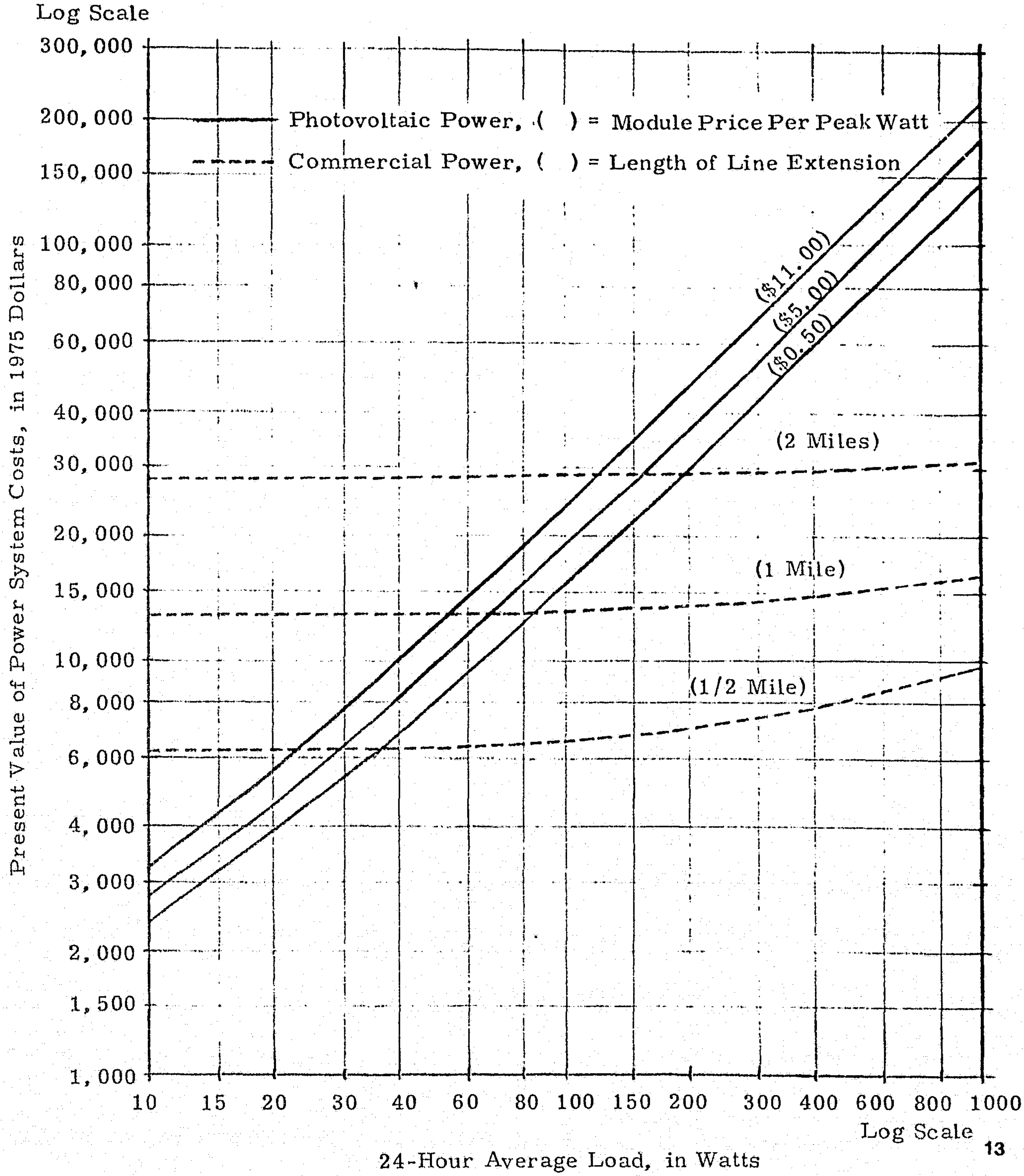
ORIGINAL PAGE IS OF POOR QUALITY

Exhibit 4

COST COMPARISON: PHOTOVOLTAIC VS. COMMERCIAL POWER

(Based on Assumptions Detailed in a Previous Exhibit)

P/A = 8.0



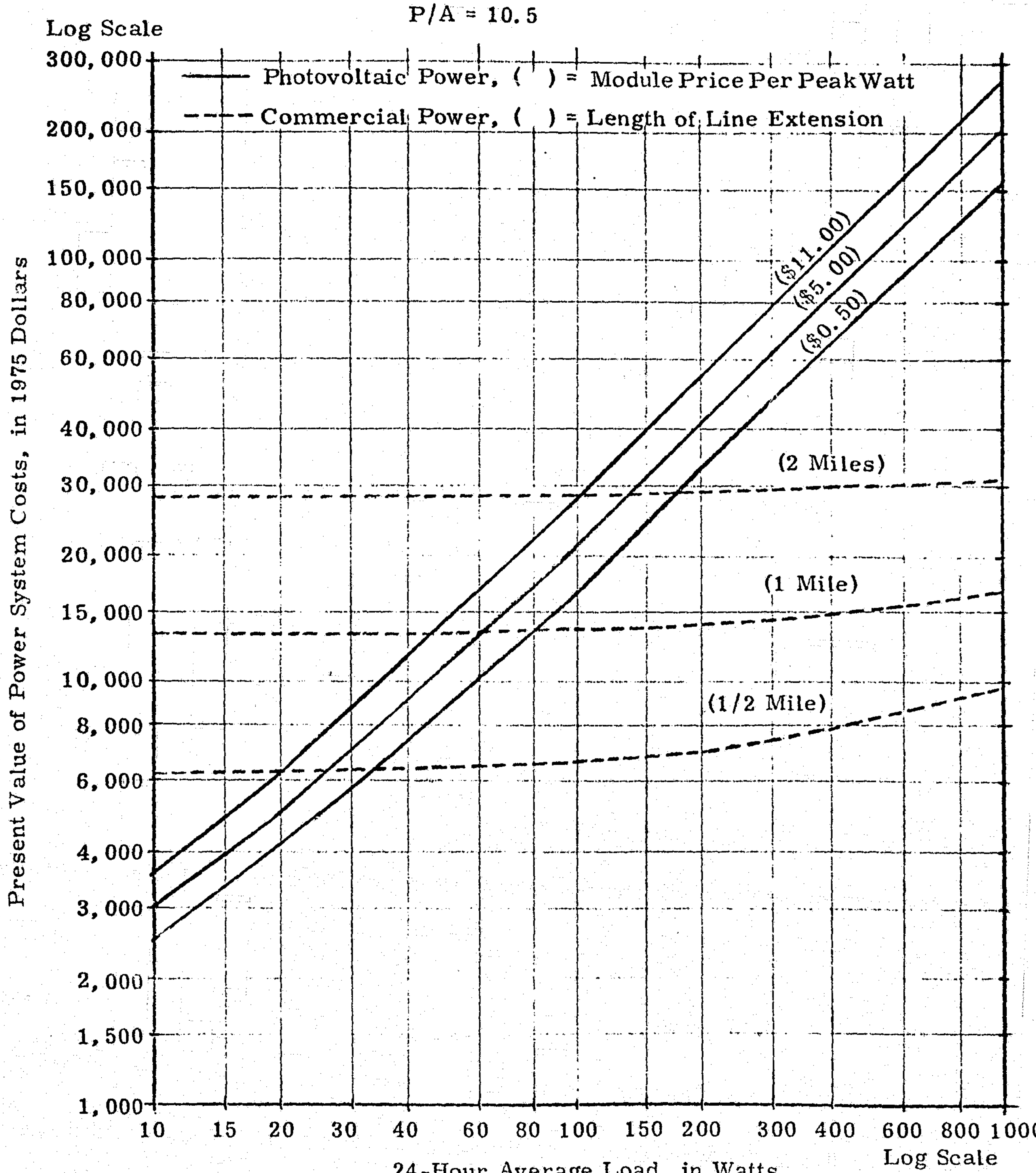
Sources: NASA; TMA

Exhibit 5

COST COMPARISON: PHOTOVOLTAIC VS. COMMERCIAL POWER

(Based on Assumptions Detailed in a Previous Exhibit)

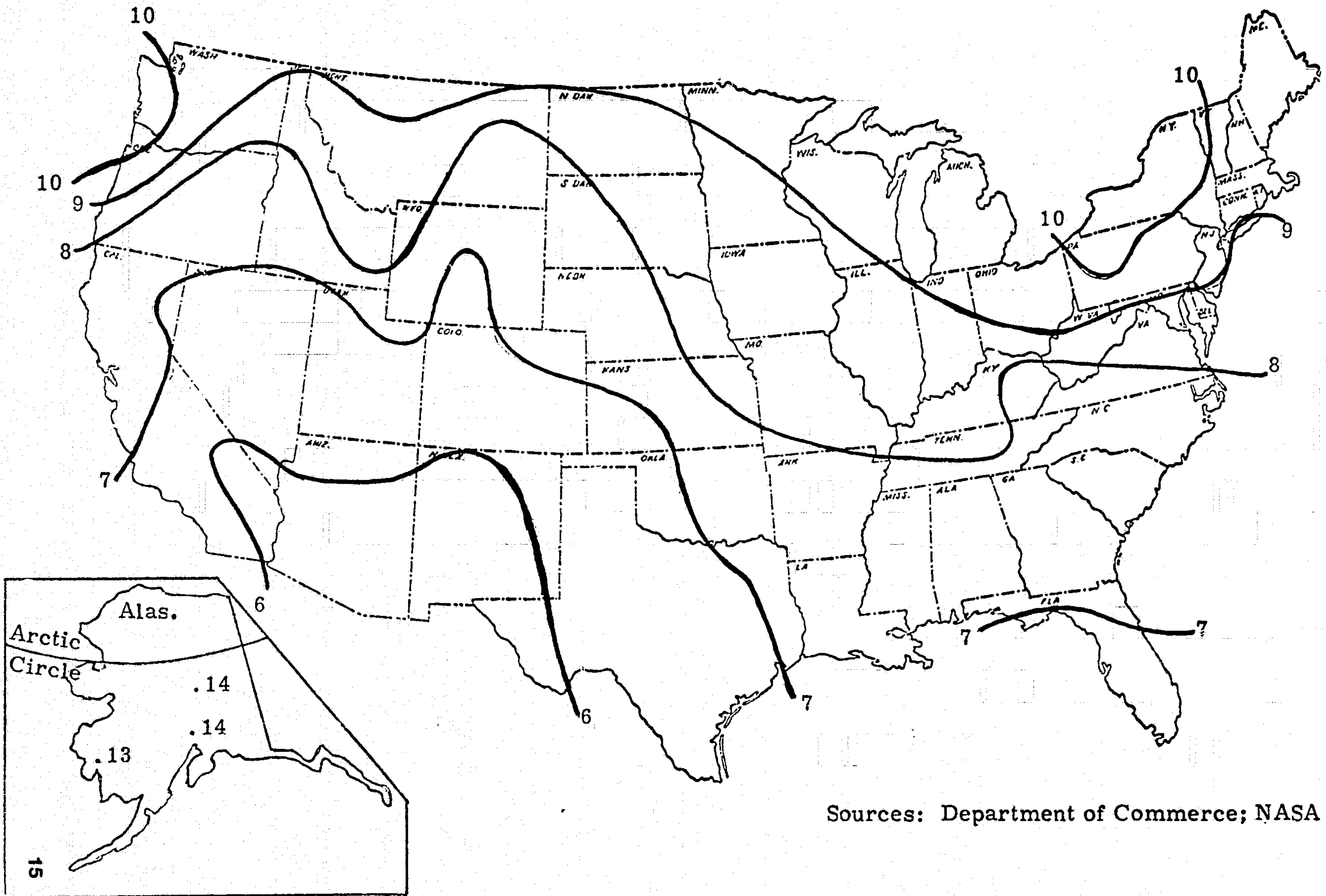
P/A = 10.5



Sources: NASA; TMA

APPROXIMATE REGIONS OF THE U. S. BY DESIGN POINT P/A RATIO

(Basis: Mean Daily Solar Radiation for the Year)



Sources: Department of Commerce; NASA

Exhibit 6

ORIGINAL PAGE IS
OF POOR QUALITY

IV. SURVEY OF HIGHWAY APPLICATIONS

A. Commercial Installations

When the survey was first planned, it was hoped that practical applications for solar electric power could be found among highway-related commercial installations, such as advertising signs, restaurants, vending installations, service stations, and the like. Interviews were conducted, therefore, with representative owners of installations of each type. These inquiries uncovered no commercial installation of any kind in which average power consumption would be less than 100 watts, and hence this avenue of investigation was discontinued.

B. Electrical Requirements of Contractors

Contractors who build roads, bridges, and highway-related service installations are obvious users of electricity who must often operate in locations where there is no utility power available. Investigation revealed that contractors' power requirements are met in a variety of ways. Small portable devices, such as flashing lights which mark obstructions at night, are frequently driven by batteries. Heavier loads which must be powered only on a temporary basis are normally driven by portable engine-generators which the contractor can move easily from place to place. Massive loads which will remain fixed for a longer period of time, such as a maintenance shop for the contractors' equipment, will normally justify an extension of the utility power line.

Despite the variety of the electrical equipment which contractors use, few instances were found in which the contractor drives a load whose equivalent continuous power consumption is less than 100 watts. Flashing barricade lights appear to be the only commonly-used apparatus which meets such a criterion. Even here, however, the problem of total wattage becomes difficult to overcome, since such flashing lights are seldom used singly, but more often in groups of ten or more. A photovoltaic power system large enough to operate a series of such lights would probably be so large as to have to be mounted on a large trailer, and would probably cost more than $10,000. The cost and size of such a piece of equipment, and its vulnerability to accidental damage and vandalism, appear to put it beyond the realm of reasonable consideration by any of the contractors interviewed.

TMA also considered the possibility that contractors using heavy construction machinery, such as bulldozers, and heavy trucks, might use a solar-powered trickle charger, which could be mounted on the vehicle itself, so as to extend the operating life of the vehicle's batteries. Here again, the response of the contractors was discouraging. Construction machinery is seldom left unused for so long a period as to cause appreciable battery discharge, and the contractors feel that present techniques for keeping batteries charged are entirely adequate.

As a result of these inquiries, TMA has concluded that prospects for solar electric power in non-governmental highway applications are poor. Attention was therefore focused on installations in which the electrical equipment would be publicly owned.

C. Electrical Loads of State Highway Equipment

TMA's investigation of government-operated highway-related electrical applications concentrated on requirements of state governments rather than municipal governments. The reason for this choice is that municipal governments, by definition, are concerned with needs in regions which are relatively densely populated. Hence municipalities seldom, if ever, encounter the necessity to extend utility power lines more than one-half mile. State governments, on the other hand, were expected to have fairly frequent requirements for electric power in locations which are remote from the existing distribution network.

Early in this stage of the investigation, it became obvious that state highway departments purchased and installed a tremendous variety of electrical equipment. Hence it was necessary to study and analyze this equipment in order to determine which types are likely to present an equivalent continuous load of 100 watts or less, so that investigation thereafter could be concentrated on needs for these particular equipment types. An analysis of the electrical loads presented by many types of highway-related equipment is presented in Appendix A. The types of equipment selected for detailed investigation were as follows:

(1) Lighting

- (a) Small-area lighting
- (b) Bridge navigation lights

(2) Signs

- (a) Directional signs (lighted)
- (b) Warning signs (lighted)
- (c) Fiber-optic signs
- (d) Variable-message signs

(3) Railroad Crossing Signals

(4) Radio Equipment

(a) VHF, UHF, and microwave repeaters
(b) CB repeaters
(c) Travelers' information transmitters

(5) Cathodic Protection Systems for Bridges

(6) Instruments

(a) Traffic counters
(b) Speed monitors
(c) Height monitors
(d) Gap monitors
(e) Fog detectors
(f) Ice detectors

(7) Motorist Aid Call Boxes

Two items appear on the foregoing list for which the equivalent continuous load exceeds 100 watts. Such an exception was made for bridge navigation lights because investigation indicated that it is frequently necessary to extend power for such lights over a distance of much more than one mile. In the case of cathodic protection for bridges, reports first published by the Department of Transportation indicated that adequate protection for an average-sized bridge could be accomplished with considerably less than 100 watts load, and TMA acted on the assumption that these reports were correct. Nevertheless, these reports proved to be based on very limited testing of protection techniques which are admittedly experimental. Reports received later from the State of California, where most of this experimentation has taken place, indicate that adequate protection can seldom be provided with as little as 100 watts power, so that solar power appears unlikely to prove economical for such applications, even if this protective technique should become widely adopted in the future.

D. Summary of State Highway Requirements

Turning to its other criterion, TMA sought to determine the amount of highway mileage maintained by each of the states, and to estimate the portion of this mileage located at least one-half mile from the nearest utility power. Investigation soon made it clear that distinctions should be made between highways of three types:

(1) Interstate highways. Because no commercial development is permitted along the Interstates, no utility power is already in place there. As a result, almost all electrical installations for lighting and sign illumination require some extension of utility power. On the other hand, the nation's Interstate highway system is now essentially complete, so that the needs for additional electrical installations along these highways are relatively small.

(2) Unpaved rural highways. Many states maintain extensive mileage of such rural highways. Nevertheless, the conclusion was soon reached that these highways could be essentially ignored because, if the highway carries so little traffic so as to remain unpaved, the state or local government will almost never find it necessary to install illuminated signs, lighting, instruments, or other equipment which would require electric power.

(3) Paved highways. The category of major interest thus becomes paved highways in rural areas where maintenance is a state responsibility. These are highways in which new installations of electrical equipment are most common, and consequently those on which TMA's investigation was centered.

Mileage of paved highways in each of the states, together with an estimate of mileage located at least one-half mile from utility power, are summarized in Exhibit 7. The exhibit shows that, in addition to 42,800 miles of Interstate highways, there are 780,000 miles of state-maintained rural paved highway in the United States. On this latter amount, approximately 89,300 miles are believed to be at least one-half mile from the nearest power line, and it is along these highways that the greatest need for solar electric power can be expected.

Nevertheless, investigation showed that electrical installations are not made along these remote highways as frequently as might be anticipated. The reason for this is that need for signs, signals, instruments and the like is dependent upon the density of traffic. Traffic density in turn, becomes highest as population centers are approached, but utility power also follows population. Consequently the need for electric power in remote areas is by no means proportional to the amount of highway mileage to be found there. For this reason, as Exhibit 7 also shows, all of the states together have found openly about 536 occasions in which it was necessary for them to extend utility power more than one-half mile over the five-year period from 1973 through 1977. Thus the average state made such an extension only twice during the course of a normal year.

As the final step in this scheme of analysis, each state was questioned as to its past and forecasted use of the low-wattage electrical equipment listed above in locations where power line extension would be necessary. Detailed tabulations of present and projected usage, together with expected need to extend utility power, are shown for most of the selected types of electrical apparatus in Appendix B. The findings of greatest interest in this analysis are summarized in Exhibit 8. The states together indicated in interviews that, over the next five years, they expect to make 442 installations of equipment of the types listed in locations where it would probably be necessary to extend utility power a distance of at least one-half mile.

In TMA's view, the total presented in Exhibit 8 represents a slight understatement of the opportunity for solar electric power for two reasons:

(1) During some of the earlier state interviews, TMA was unaware of some potential applications, or was unable to reach the appropriate highway official, so that the investigation in the interview program did not cover all applications in all cases.

(2) In other cases, the interviewee described only those requirements of which he was presently aware, whereas over a period of five years, other unanticipated requirements are almost certain to occur. For example, it is common practice to install some type of lighted warning device in locations where a fatal accident has occurred. Nevertheless, it is usually impossible for highway officials to predict how many such accidents will occur over a five-year period, or where they will take place.

As a result, TMA has adjusted upward the total number of opportunities for solar installations as shown in Exhibit 9. By TMA's estimate, a total of 653 low-wattage electrical installations are likely to be made over the next five years in locations which are more than one-half mile from existing utility power. Nevertheless, even here, the average state will encounter only two or three such opportunities in the course of a normal year.

Exhibit 7

ESTIMATED PROXIMITY OF STATE HIGHWAYS TO COMMERCIAL POWER

(1) State	(2) Miles of Interstate Highway	(3) Miles of Rural, Paved, State-Maintained Highway*	(4) Est. Miles of Col. (3) Farther than 1/2 Mile From Power Lines	(5) Percent of Col. (3) in Col. (4)	(6) Est. No. of Times Extended Power Lines > 1/2 Mile, 1973-1977
Alabama	900	20,000	400	2	5
Alaska	0	3,000	1,200	40	30
Arizona	1,170	6,000	2,400	40	1
Arkansas	530	14,000	280	2	3
California	3,300	14,000	4,900	35	10
Colorado	1,000	8,000	160	2	0
Connecticut	340	2,000	120	6	8
Delaware	40	4,000	40	1	0
Florida	1,400	10,000	400	40	13
Georgia	1,150	18,000	180	1	1
Idaho	620	5,000	2,000	40	20
Illinois	1,750	13,000	2,000	15	40
Indiana	1,130	10,000	2,000	20	12
Iowa	790	9,000	540	6	5
Kansas	830	10,000	100	1	0
Kentucky	740	24,000	480	2	4
Louisiana	720	16,000	160	1	0
Maine	320	11,000	330	3	1
Maryland	360	5,000	500	1	50
Massachusetts	450	2,000	200	10	15
Michigan	1,200	8,000	800	10	4
Minnesota	920	11,000	1,100	10	5
Mississippi	700	10,000	500	5	7
Missouri	1,200	32,000	320	1	0
Montana	1,200	6,000	3,000	50	2

* Includes all Interstate mileage

(1) State	(2) Miles of Interstate Highway	(3) Miles of Rural, Paved, State-Maintained Highway*	(4) Est. Miles of Col. (3) Farther than 1/2 Mile From Power Lines	(5) Percent of Col. (3) in Col. (4)	(6) Est. No. of Times Extended Power Lines > 1/2 Mile, 1973-1977
Nebraska	500	10,000	1,000	10	21
Nevada	540	7,000	6,800	97	6
New Hampshire	220	3,000	90	3	0
New Jersey	390	2,000	20	1	5
New Mexico	1,000	12,000	3,600	30	2
New York	1,300	12,000	240	2	0
North Carolina	840	64,000	4,500	7	23
North Dakota	580	7,000	3,100	30	12
Ohio	1,600	17,000	3,400	20	2
Oklahoma	810	13,000	1,300	10	0
Oregon	740	10,000	1,500	15	5
Pennsylvania	1,600	43,000	860	2	50
Rhode Island	100	900	0	0	0
South Carolina	770	33,000	990	3	5
South Dakota	700	9,000	2,700	30	0
Tennessee	1,000	8,000	800	10	0
Texas	3,200	62,000	9,300	15	104
Utah	950	5,000	3,500	70	4
Vermont	320	3,000	510	17	7
Virginia	1,100	50,000	500	1	0
Washington	770	17,000	8,500	50	50
West Virginia	520	23,000	5,800	25	0
Wisconsin	580	11,000	6,600	6	2
Wyoming	920	6,000	600	10	2
Rounded Totals	42,800	780,000	89,300	11	536

*Includes all Interstate mileage

Sources: Federal Highway Administration; TMA

Exhibit 8

SUMMARY OF ESTIMATED OPPORTUNITIES FOR PHOTOVOLTAIC POWER IN SELECTED HIGHWAY APPLICATIONS 1978-1983

(Estimated Number of Installations Requiring Power Line Extensions of a Half-Mile or More)

	Area Lighting	Navigation Lights*	Lighted Regulatory and Warning Signs	Fiber-Optic Signs	Variable-Message Signs (excl. Lamp-Matrix)	Lighted Directional Signs	Railroad Crossing Signals	VHF/UHF FM and Microwave Radio	CB Relays
Alabama	-	3	-	-	-	-	10	-	-
Alaska	-	-	-	-	-	-	-	-	-
Arizona	-	-	-	-	-	-	2	-	-
Arkansas	-	2	-	-	-	-	-	-	-
California	1	-	3	-	-	-	-	7	-
Colorado	4	-	-	-	-	-	-	-	-
Connecticut	-	-	-	-	-	-	-	-	-
Delaware	-	-	-	-	-	-	-	-	-
Florida	-	5	2	3	3	-	-	-	-
Georgia	-	-	-	-	-	-	-	-	-
Idaho	-	-	-	-	-	7	12	-	-
Illinois	-	-	3	-	-	-	-	-	-
Indiana	-	-	-	-	-	-	-	-	-
Iowa	-	-	-	-	-	-	-	-	-
Kansas	-	-	-	-	-	-	-	-	-
Kentucky	-	-	1	-	-	10	-	-	-
Louisiana	-	-	-	-	-	-	-	-	-
Maine	-	-	-	-	-	-	-	-	-
Maryland	-	-	-	-	-	25	-	-	-
Massachusetts	-	-	5	-	3	-	-	-	-
Michigan	-	-	-	-	-	-	-	-	-
Minnesota	-	-	2	-	-	-	-	-	-
Mississippi	-	-	2	-	-	-	5	-	-
Missouri	-	-	-	-	-	-	1	1	-
Montana	-	-	-	-	-	-	-	-	-

- indicates zero

* A criterion of a two-mile line extension was used for navigation lights to compensate for their high power requirement.

Exhibit 8 (cont'd.)

SUMMARY OF ESTIMATED OPPORTUNITIES FOR PHOTOVOLTAIC POWER IN SELECTED HIGHWAY APPLICATIONS 1978-1983

(Estimated Number of Installations Requiring Power Line Extensions of a Half-Mile or More)

	Area Lighting	Navigation Lights*	Lighted Regulatory and Warning Signs	Fiber-Optic Signs	Variable-Message Signs (excl. Lamp-Matrix)	Lighted Directional Signs	Railroad Crossing Signals	VHF/UHF FM and Microwave Radio	CB Relays
Nebraska	-	-	10	-	-	-	-	-	-
Nevada	-	-	-	-	-	-	2	1	-
New Hampshire	-	-	-	-	-	-	-	-	-
New Jersey	-	-	-	-	-	-	-	-	-
New Mexico	-	-	2	-	-	-	-	-	-
New York	-	-	-	-	-	-	-	-	-
North Carolina	-	-	7	-	-	-	20	-	-
North Dakota	-	-	8	-	-	-	-	-	-
Ohio	-	-	-	-	-	-	-	-	-
Oklahoma	-	-	-	-	-	-	-	-	-
Oregon	-	-	-	-	-	-	-	1	-
Pennsylvania	-	-	-	-	-	7	-	-	-
Rhode Island	-	-	-	-	-	-	-	-	-
South Carolina	-	1	3	-	-	-	4	-	-
South Dakota	-	-	-	-	-	-	-	-	-
Tennessee	-	-	-	-	-	-	-	-	-
Texas	-	5	-	-	-	-	30	-	-
Utah	-	-	4	-	-	-	-	-	-
Vermont	-	-	-	-	-	-	-	-	-
Virginia	-	-	-	-	-	-	-	-	-
Washington	-	-	25	-	-	-	-	8	-
West Virginia	-	-	-	-	-	-	-	-	-
Wisconsin	-	-	-	-	-	-	-	-	-
Wyoming	-	-	-	-	-	1	-	-	-
Totals	5	16	77	3	6	50	86	18	0

- indicates zero

* A criterion of a two-mile line extension was used for navigation lights to compensate for their high power requirement.

Exhibit 8 (cont'd.)

SUMMARY OF ESTIMATED OPPORTUNITIES FOR PHOTOVOLTAIC POWER IN SELECTED HIGHWAY APPLICATIONS

1978-1983

(Estimated Number of Installations Requiring Power Line Extensions of a Half-Mile or More)

	Travelers' Information Radio	Cathodic Protection for Bridge Decks	Traffic Counters	Speed Monitors	Height Monitors	Inter-Vehicle Gap Monitors	Fog and Ice Detectors	Portable Power Supply	Call Boxes
Alabama	-	-	-	-	-	-	-	-	-
Alaska	-	-	-	-	-	-	5	-	-
Arizona	-	-	2	-	-	-	-	-	-
Arkansas	-	-	-	-	-	-	-	-	-
California	-	5	-	-	-	-	-	-	-
Colorado	-	-	-	-	-	-	-	-	-
Connecticut	-	-	-	-	-	-	-	-	150
Delaware	-	-	-	-	-	-	-	-	-
Florida	-	-	-	-	-	-	-	-	-
Georgia	-	-	-	-	-	-	-	-	-
Idaho	-	-	-	1	-	-	-	-	-
Illinois	-	-	-	-	1	-	-	-	-
Indiana	-	-	-	-	-	-	-	-	-
Iowa	-	-	-	-	-	-	-	-	-
Kansas	-	-	-	-	-	-	-	-	-
Kentucky	-	-	-	-	-	-	-	-	-
Louisiana	-	-	-	-	-	-	-	-	-
Maine	-	-	-	-	-	-	-	-	-
Maryland	-	-	-	-	-	-	-	-	-
Massachusetts	-	-	3	-	-	-	1	-	-
Michigan	-	-	-	-	-	-	-	-	-
Minnesota	-	-	-	-	-	-	-	-	-
Mississippi	-	-	-	-	-	-	-	-	-
Missouri	-	-	-	-	-	-	-	-	-
Montana	-	-	-	-	-	-	-	-	-

- indicates zero

Exhibit 8 (cont'd.)

SUMMARY OF ESTIMATED OPPORTUNITIES FOR PHOTOVOLTAIC POWER IN SELECTED HIGHWAY APPLICATIONS 1978-1983

(Estimated Number of Installations Requiring Power Line Extensions of a Half-Mile or More)

	Travelers' Information Radio	Cathodic Protection for Bridge Decks	Traffic Counters	Speed Monitors	Height Monitors	Inter-Vehicle Gap Monitors	Fog and Ice Detectors	Portable Power Supply	Call Boxes
Nebraska	-	-	-	-	-	-	1	-	-
Nevada	-	-	-	-	-	-	-	-	-
New Hampshire	-	-	-	-	-	-	-	-	-
New Jersey	-	-	-	-	-	-	-	-	-
New Mexico	-	-	-	-	-	-	-	-	-
New York	-	-	-	-	-	-	-	-	-
North Carolina	-	-	-	-	-	-	1	-	-
North Dakota	-	-	-	-	-	-	-	-	-
Ohio	-	-	-	-	-	-	-	-	-
Oklahoma	-	-	-	-	-	-	-	-	-
Oregon	-	-	-	-	-	-	-	-	-
Pennsylvania	-	-	-	-	-	-	-	-	-
Rhode Island	-	-	-	-	-	-	-	-	-
South Carolina	-	-	-	-	-	-	-	-	-
South Dakota	-	-	-	1	-	-	1	-	-
Tennessee	-	-	-	-	-	-	-	-	-
Texas	-	-	-	-	-	-	-	-	-
Utah	-	-	5	-	-	-	-	-	-
Vermont	-	-	-	-	-	-	-	-	-
Virginia	-	-	-	-	-	-	-	-	-
Washington	-	-	-	-	4	-	-	-	-
West Virginia	-	-	-	-	-	-	-	-	-
Wisconsin	-	-	-	-	-	-	-	-	-
Wyoming	-	-	-	-	-	-	-	-	-
Totals	0	5	10	2	5	0	9	0	150

- indicates zero

Exhibit 9

PROJECTED OPPORTUNITIES FOR PHOTOVOLTAIC INSTALLATIONS IN SELECTED APPLICATIONS ON STATE HIGHWAYS

Application	Projected Installations Suitable for Photovoltaic Power, 1978-83: From Interviews	TMA Projections
1. Lighting		
(a) Area lighting, 1 or 2 fixtures, low wattage	5	25
(b) Navigation light systems	16	20
2. Signs		
(a) Warning signs with lights	77	100
(b) Fiber-optic warning signs	3	15
(c) Variable-message signs, excluding lamp matrix types	6	10
(d) Lighted directional signs on expressways	50	50
3. Railroad-Highway Grade Crossing Signals	86	100
4. Radio Installations		
(a) VHF/UHF FM and microwave	18	30
(b) CB relays	0	5
(c) Travelers' information radio transmitters	0	3
5. Cathodic Protection for Bridge Decks	5	50
6. Instruments		
(a) Traffic counters	10	15
(b) Speed monitors	2	5
(c) Height monitors	5	5
(d) Inter-vehicle gap monitors	0	0
(e) Fog detectors	2	10
(f) Ice detectors	7	50
7. Portable Power Supply for Equipment Evaluation	0	10
8. Motorist Aid Call Boxes	150	150
Total	442	653

V. EVALUATION OF FINDINGS OF FIRST PHASE

A. Evaluation of the Selected Applications

By agreement with NASA, the various power applications found among the states were evaluated on the basis of a scheme suggested in TMA's original proposal. This scheme is summarized in Exhibit 10.

When the foregoing evaluation formula is applied to the list of equipment applications on which TMA's field investigations focused, the tabulation shown in Exhibit 11 results. Total point ratings can be seen to vary over an extremely wide range. Nevertheless, the highest point totals can be seen to fall within the "Sign" category, with "Instruments" taking second place.

B. Highway Applications as a Photovoltaic Market

While it was judged important to get greater detail as to whether or not the state's highway department would be ready to purchase solar electric power equipment for their actual requirements in the highest-rated categories, it appeared equally vital to gain insight into the problems which a solar electric power supplier might encounter in attempting to make sales to this market.

Despite the obvious desirability of identifying and cultivating the best possible applications for photovoltaic power, the findings of the first phase of the study introduced doubt as to whether the differences between these various applications were truly significant. As seen by a solar power manufacturer, all of these applications involve customers of the same type with similar backgrounds and interests. In each case, the equipment is likely to be bought in small quantities by an end-user who is relatively unfamiliar with solar electric power. From the technical standpoint, each application represents a low-wattage load and an out-door installation. The technical requirements of each of these applications can easily be met with existing equipment that can be purchased from any of several established photovoltaic manufacturers. From the point of view of a manufacturer wishing to develop the highway market for solar power supplies, therefore, it seemed entirely possible that the similarities between these applications would loom far larger than their differences.

C. Directions Established for Phase II

After review and discussion of the findings of the first phase of this investigation, TMA was requested by NASA to concentrate its activities in Phase II as follows:

(1) A detailed investigation of the highway sign industry, and of opportunities there for solar electric power, following the scheme of analysis suggested in the original objectives of the program.

(2) Direct approaches to the highway departments of several selected states so as to review their anticipated power requirements in greater detail, and to assess their readiness to consider, and prospectively to buy, solar power for these installations.

Exhibit 10

SCHEME OF NUMERICAL EVALUATION OF PHOTOVOLTAIC APPLICATIONS

A. Overall Scheme of Evaluation for Each Application

	Evaluation Element	Weighting Factor	Method to Determine
1.	Market opportunity, 1979	20	Formula
2.	Market opportunity, 1986	40	Formula
3.	Visibility, promotional value	10	Subjective
4.	Enthusiasm of interviewees	15	Subjective
5.	Opinion of TMA	15	Subjective
	Total	100	

B. Formula for Approximating the Size of the Market Opportunity

$$MO = \frac{P \times N}{(P \times N)_{max}} \times W$$

Where P = Required 24-hour average power capability, in watts

N = Number of installations in which the present value of installation and operating costs is expected to favor photovoltaic power

$(P \times N)_{max}$ = The maximum (P x N) value among all applications being considered

W = Weighting factor (see above)

C. Visibility and Promotional Value	Points Awarded
1. If the general motoring public is very likely to see the application, understand its purpose, and approve of it	10
2. If the general motoring public is unlikely to see the application, but would understand and approve of it if it were explained and promoted	7
3. If the general motoring public is very likely to see and to understand the application, but most would not approve of it	5
4. If the general motoring public is unlikely to see or to understand the purpose of the application	0
D. Enthusiasm of Interviewees	
1. If many interviewees were eager to try photovoltaic power for the application, with little regard for cost	15
2. If the interviewees, in general, would be in favor of photovoltaic power in situations where it was competitive in cost and reliability with other means of power supply	10
3. If the interviewees, in general, would consider using photovoltaic power in situations where it was competitive in cost and reliability with other means of power supply	5
4. If the interviewees, in general, felt there would never be a situation where photovoltaic power would be competitive, or would not use photovoltaic power even if it were competitive	0

E. Opinion of TMA	Points Awarded
1. If the application appears to TMA to be one for which photovoltaic power is extremely suitable and which presents a very good marketing opportunity in both the short and long runs	15
2. If the application appears to TMA to be one for which photovoltaic power is extremely suitable, but which may have limited opportunity in the near future or after several years	10
3. If the application appears to TMA to be only marginally suitable for photovoltaic power, even though the market potential for the application device may be bright	5
4. If TMA foresees little or no possibility that the application will ever provide enough opportunity to warrant consideration by photovoltaic manufacturers	0

Exhibit 11

NUMERICAL EVALUATION OF HIGHWAY-RELATED PHOTOVOLTAIC APPLICATIONS

( ) = Assigned Weight, 100-Point Scale

Application	1979 Market (20)	1986 Market (40)	Visi-bility (10)	Enthu-siasm (15)	TMA's Opinion (15)	Total (100)
1. Lighting						
(a) Area (low-wattage)	1	10	10	10	5	36
(b) Navigation	11	23	7	15	5	61
2. Signs						
(a) Warning	18	40	10	10	15	93
(b) Fiber optic	1	3	10	10	15	39
(c) Variable message	2	5	10	10	15	42
(d) Directional	20	32	10	10	10	82
3. Railroad Crossing Signals	4	7	10	5	15	41
4. Radio Installations						
(a) VHF, UHF, microwave	3	7	7	15	15	47
(b) CB repeaters	0	0	10	5	10	25
(c) Travelers' info.	0	2	10	7	10	29
5. Cathodic Protection	0	1	0	10	15	26
6. Instruments						
(a) Counters	0	0	10	5	10	25
(b) Speed monitors	0	0	5	10	10	25
(c) Height monitors	2	3	10	10	15	40
(d) Gap monitors	0	0	5	10	5	20
(e) Fog detectors	5	17	10	10	5	47
(f) Ice detectors	2	33	10	10	15	70
7. Portable Power Supply	0	6	10	10	15	31
8. Motorist Aid Call Boxes	0	0	10	0	0	10

VI. HIGHWAY SIGNS AS A POTENTIAL MARKET FOR SOLAR ELECTRIC POWER

A. The Highway Sign Market

A summary and description of selected types of highway signs which use electric power is provided in Exhibit 12. As indicated previously, TMA's investigations concentrated on four types of highway signs which typically impose equivalent continuous electrical loads of less than 100 watts:

(1) Directional signs.

(2) Regulatory and warning signs.

(3) Variable message signs.

(4) Fiber-optic signs.

Viewed as businesses, however, these four types of signs are by no means of equal importance, as Exhibit 13 makes clear. Out of a total of $236-million worth of signs erected in 1977, slightly more than half consisted of directional signs, and most of the remainder were regulatory and warning signs. Variable message and fiber-optic signs are believed to have contributed only about 2% of the total dollar volume.

Further detail on the composition of each of these four segments of the sign market is shown in Exhibit 14. Here it becomes apparent that substantial portions of these segments of the sign market are, for various reasons, inappropriate for photovoltaic power. In the case of directional signs, for example, approximately 85% involve no illumination whatsoever. In the case of regulatory and warning signs, the percentage that uses beacons or illumination is less than 0.4%. In the case of fiber-optic and variable message signs, on the other hand, despite the relatively small number of signs installed, all signs do use electric power. Note: these types are relatively new to the marketplace.

B. The Highway Sign Industry

The structure of the highway sign industry is best understood by reference to Exhibits 15 through 18, which, for each of the four principal types of highway signs, illustrates how signs and sign components flow from their respective manufacturers to the various organizations which purchase and install them. These exhibits also illustrate the estimated 1977 value of the goods and services sold during 1977 in connection with the selected types of signs, and indicate the position in the industry which photovoltaic manufacturers would occupy if solar power supplies were to be used on sign applications.

This flow of products and services can best be appreciated through detailed consideration of Exhibit 15, which applies only to directional signs. As the exhibit indicates, it is estimated that highway departments spent $146-million in 1977 for directional signs, including, in some cases, the erection of the signs. About 80% of this amount was spent by state highway departments, and the balance by local street departments, turnpikes, and port authorities. In almost all cases, these signs were purchased through public bidding, but they were purchased from several kinds of sources. The most significant source, providing $60-million of the total, was road construction contractors who erected directional signs as one of many items included in major road construction contracts. Another major source, worth an estimated $34-million, was the maintenance departments of the various states, which erected signs that were manufactured, in many cases, in prisons or sign shops operated by the state itself. The remainder of the signs were purchased from integrated sign manufacturers, who have their own facilities for sign erection, or from commercial sign erectors, who put up signs manufactured by others. In some cases, highway engineering consultants may have had some influence on the type of sign used and on the detailed specifications.

When a directional sign is erected either by a state agency or by a commercial sign erector, the sign itself is purchased from an outside source. Although state-operated facilities made an estimated $18-million worth of directional signs in 1977, commercial sign manufacturers made an estimated $24-million worth. When the sign is bought from an outside agency, or manufactured by an integrated sign manufacturer, the electrical equipment used with the sign, if any, is normally purchased from a separate lighting or signal equipment manufacturer. These companies sold an estimated $13-million worth of electrical equipment for directional signs in 1977, of which $3-million was bought by state government maintenance departments, $4-million by commercial sign erectors, and $6-million by integrated sign manufacturing companies. Were directional signs to be provided with solar electric power supplies, the photovoltaic manufacturer would probably fit into the sign industry at this same level. Therefore, the state highway department would request bids on a directional sign for which a solar electric power supply would be specified, and this specification would be passed on by the road construction contractor, sign erector, or integrated sign manufacturer to one or more suppliers of solar electric power supplies who would then submit bids in response.

If we look at the other exhibits in this series describing product flow for regulatory and warning signs, fiber-optic signs, and variable message signs, we see much the same type of industry structure, although both fiber-optic and variable message signs tend to be manufactured by companies which are specialists in their respective types of products.

From the standpoint of a manufacturer of solar electric power supplies, the highway sign market would be a difficult one to cover. A relatively small number of manufacturers occupy leadership positions in the sign industry, as described in Exhibit 19. With respect to the four types of signs of principal interest here, however, Exhibit 20 shows that no company dominates the business. The two largest manufacturers, Interstate and Fosco, appear to enjoy volumes of only $9-million and $13-million respectively out of an industry volume of $235-million, and most of the industry is made up of relatively small firms, with annual sales of $1-3 million, who do business primarily on a local or regional basis. Bearing in mind that only a tiny fraction of these signs are located over one-half mile from utility power (as shown in Exhibit 14) the solar power manufacturer would be obliged to maintain contact with a very large number of firms among whom opportunities to sell would occur very seldom.

C. Outlook for Solar Electric Power in Sign Applications

If the highway sign market is considered in its entirety, it is large and reasonably fast-growing. For only the four types of signs covered in this investigation, 1977 expenditures, as noted above, were $235-million, and further growth may be expected in the future. For example, as Exhibit 21 illustrates, total governmental highway expenditures of all types have grown approximately 50% over the period from 1973 to 1978, an average growth rate of more than 8% a year. Although intensified popular insistence on tax reduction may have a depressive effect on highway budgets, it appears likely that future expenditures for highway signs will at least keep pace with the effects of inflation.

Nevertheless, as has been seen, the percentage of highway signs which require electric power of any kind is extremely small, and the percentage which are located at least one-half miles from the nearest utility power is even smaller. Although conditions will vary greatly from one state to another, it appears that in a typical state, the need to extend a utility power line at least one-half miles in order to illuminate a highway sign will occur only once or twice in a year. It is not surprising, therefore, that the photovoltaic industry has not endeavored to pursue sales opportunities which occur on such a scattered and infrequent basis.

TMA has endeavored to determine whether the major manufacturers of highway signs would be interested in offering solar electric power supplies as optional accessories for their products. As indicated in Exhibit 22, their responses have generally reflected very little enthusiasm.

A major factor affecting the attitude of sign manufacturers is the contrast between the cost of the sign itself and that of the photovoltaic power supply which would have to be used with it. To illustrate this point, Exhibit 23 compares representative costs for the types of highway signs under consideration with the 1978 cost of the solar electric power equipment needed to operate such a sign in a typical U. S. location (St. Louis, Missouri). As an example, consider the case of an erector of regulatory and warning signs, whose product has a typical selling price of $190. It is not surprising that such an erector has no interest in assuming the risk and responsibility involved in selling a solar electric power supply when such a supply would carry a price of nearly $20,000. About the only case where a greater degree of interest can be expected is that of variable message signs owing to the fact that here the signs themselves are relatively expensive compared to the power supplies which would be needed to operate them.

In view of the foregoing, it appears that the highway sign industry cannot be expected to lead the way in the introduction of solar electric power, since it has little to gain through the use of non-utility power. In fact, in TMA's view, the organizations with the most to gain from the use of solar power in properly chosen applications are the states themselves. If persuaded of this fact, the states then need merely specify that their highway signs be furnished with solar electric power, either as an absolute specification or as an alternative. Once this is done, the contractors and sign erectors bidding on the business will take the necessary steps to offer the solar equipment specified, and the normal mechanism of supply in this industry will begin to operate. Even though the sign industry now knows next to nothing about solar electric power, it can be expected to learn quickly once evidence of actual demand is shown to exist.

Exhibit 12

DESCRIPTION OF TYPES OF HIGHWAY SIGNS WHICH MAY REQUIRE POWER

DIRECTIONAL SIGNS

Ground-Mounted

Overhead

- Otherwise known as guide signs or green signs.
- Used primarily on interstate and other limited-access highways to warn motorists of approaching exits and entrances.
- May be ground-mounted at the side of the roadway or mounted overhead on overpasses or sign trusses.
- Ground-mounted signs are virtually never illuminated, but, in many states, some or all overhead signs are illuminated.

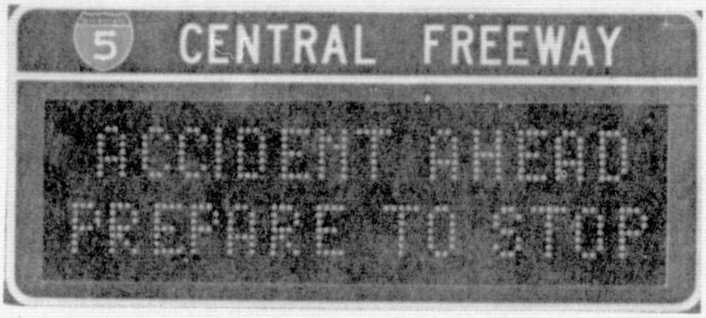
REGULATORY AND WARNING SIGNS

Regulatory Sign
With Beacon

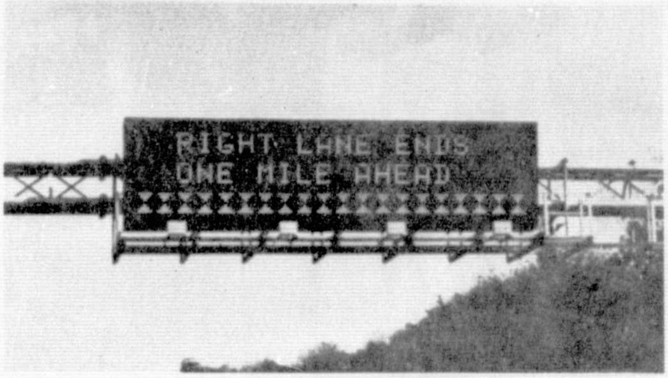
Warning Sign
With Beacon

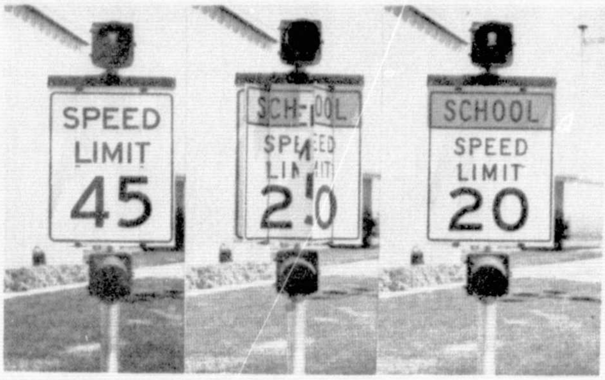
- Regulatory signs include "Stop," "Speed Limit," and "No Left Turn" signs.
- Warning signs include curve warning, "Traffic Signals Ahead," and "Slow" signs.
- Used on all types of highways and streets.
- Mounted at the side of the roadway.
- Flashing beacons are used with a sign where special emphasis is needed.

VARIABLE-MESSAGE SIGNS



Lamp Matrix Sign





Disc Matrix Sign

Flap Sign

- Many types available, but the most common are lamp matrix types, disc matrix types, and flap types.

- Lamp Matrix Signs are fully-variable, in that they can display any message small enough to fit on the sign. Characters are formed by small light bulbs. Usually under computer control. Signs consume large amounts of power compared to other variable-message sign types. Require frequent bulb replacement.

- Disc Matrix Signs are fully variable. Characters are formed by small discs which flip to expose either a dark side or a bright side. Usually under computer control. Sign consumes very little power, but is usually illuminated at night.

- Flap Signs are capable of only two different messages which are printed on the signs. To change the message, a motor rotates sections of the sign face. Often equipped with one or two flashing beacons.

ORIGINAL PAGE IS
OF POOR QUALITY

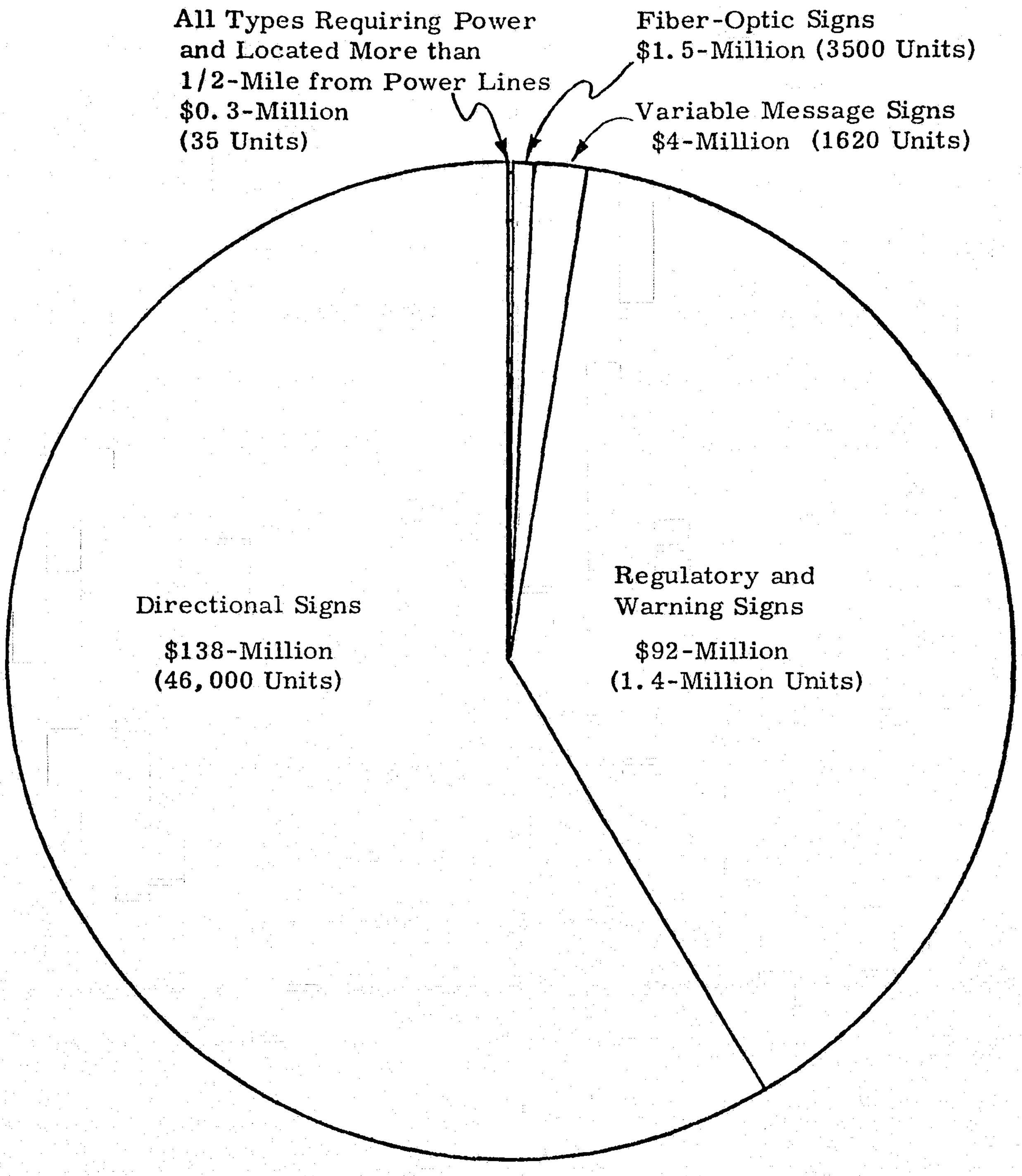
FIBER-OPTIC SIGNS

Fiber-Optic Pedestrian Signal

- Most commonly applied as pedestrian signals or as lane control signals for reversible-lane highways.
- Uses low-wattage light source.
- Better readability with lower power consumption than other types used in the same applications.

Exhibit 13

ESTIMATED BREAKDOWN OF ALL HIGHWAY SIGN INSTALLATIONS BY TYPE



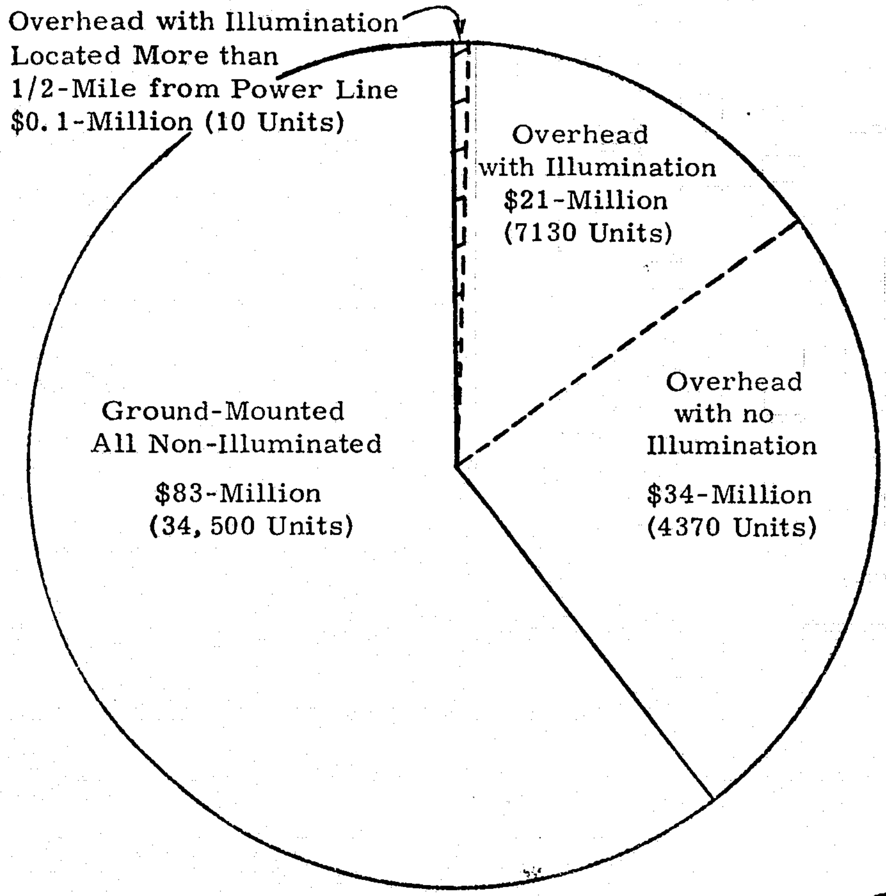
Total Value of Erection Contracts in 1977:

$236-Million

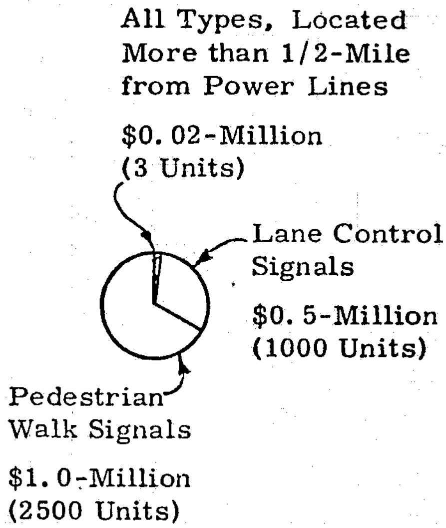
(1.45-Million Units)

Exhibit 14

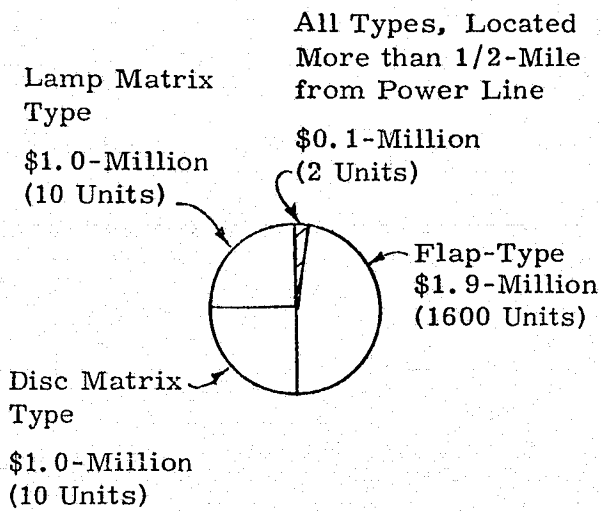
BREAKDOWN OF 1977 SIGN INSTALLATIONS IN DETAIL



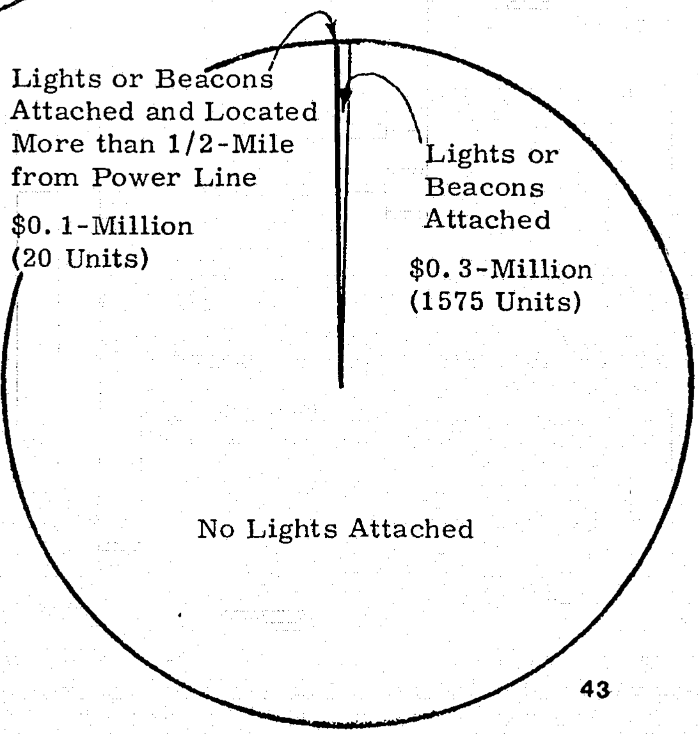
Directional Signs



Fiber-Optic Signs



Variable Message Signs



Regulatory and Warning Signs

Exhibit 15

FLOW OF DIRECTIONAL SIGNS AND COMPONENTS

WITH ESTIMATED VALUE OF MATERIALS ON EACH PATH

(M = Millions)

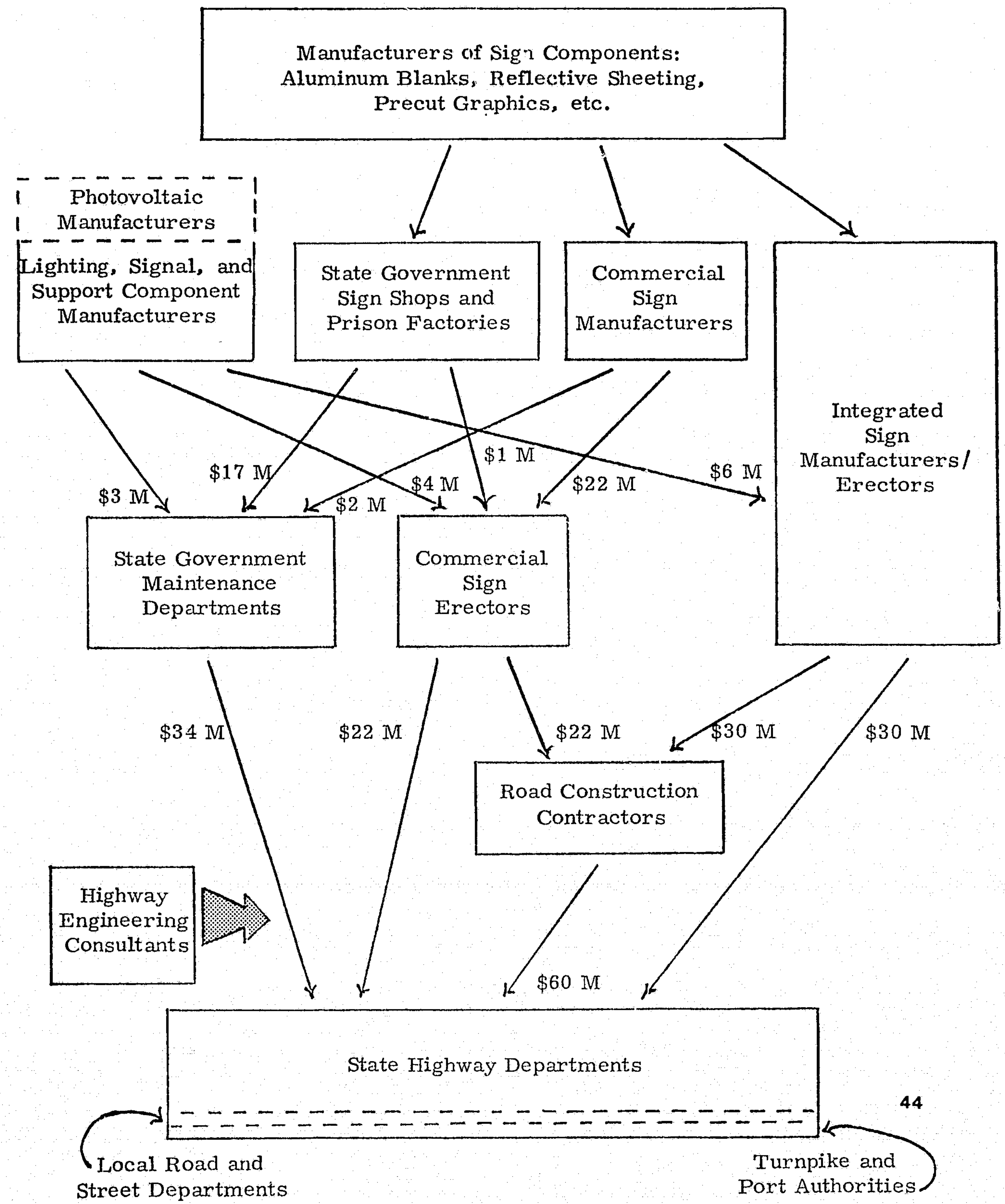


Exhibit 16

FLOW OF REGULATORY AND WARNING SIGNS AND COMPONENTS WITH ESTIMATED VALUE OF MATERIALS ON EACH PATH IN 1977

(M = Millions)

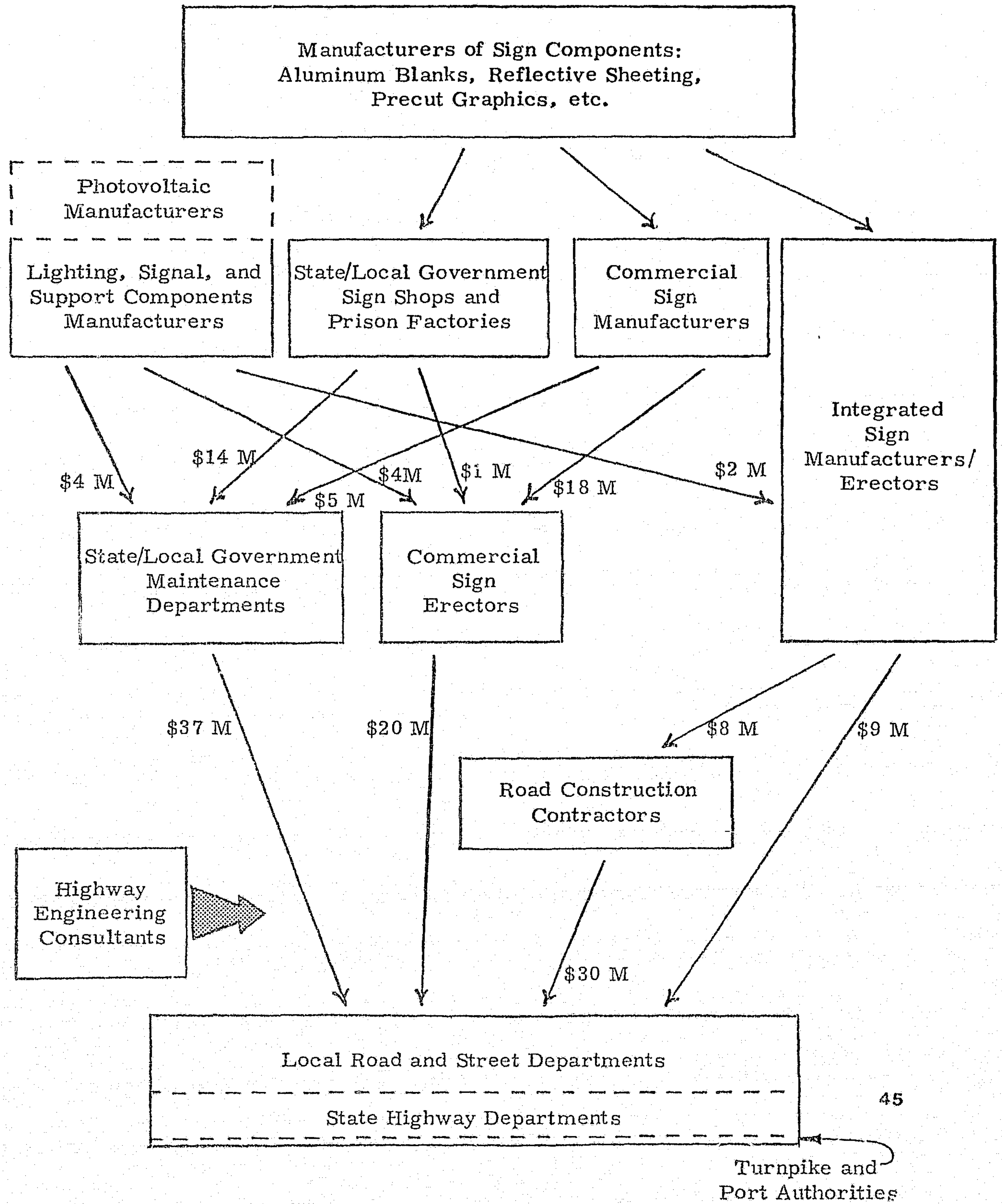


Exhibit 17

FLOW OF VARIABLE-MESSAGE SIGNS AND COMPONENTS WITH ESTIMATED VALUE OF MATERIALS ON EACH PATH IN 1977

(M = Millions)

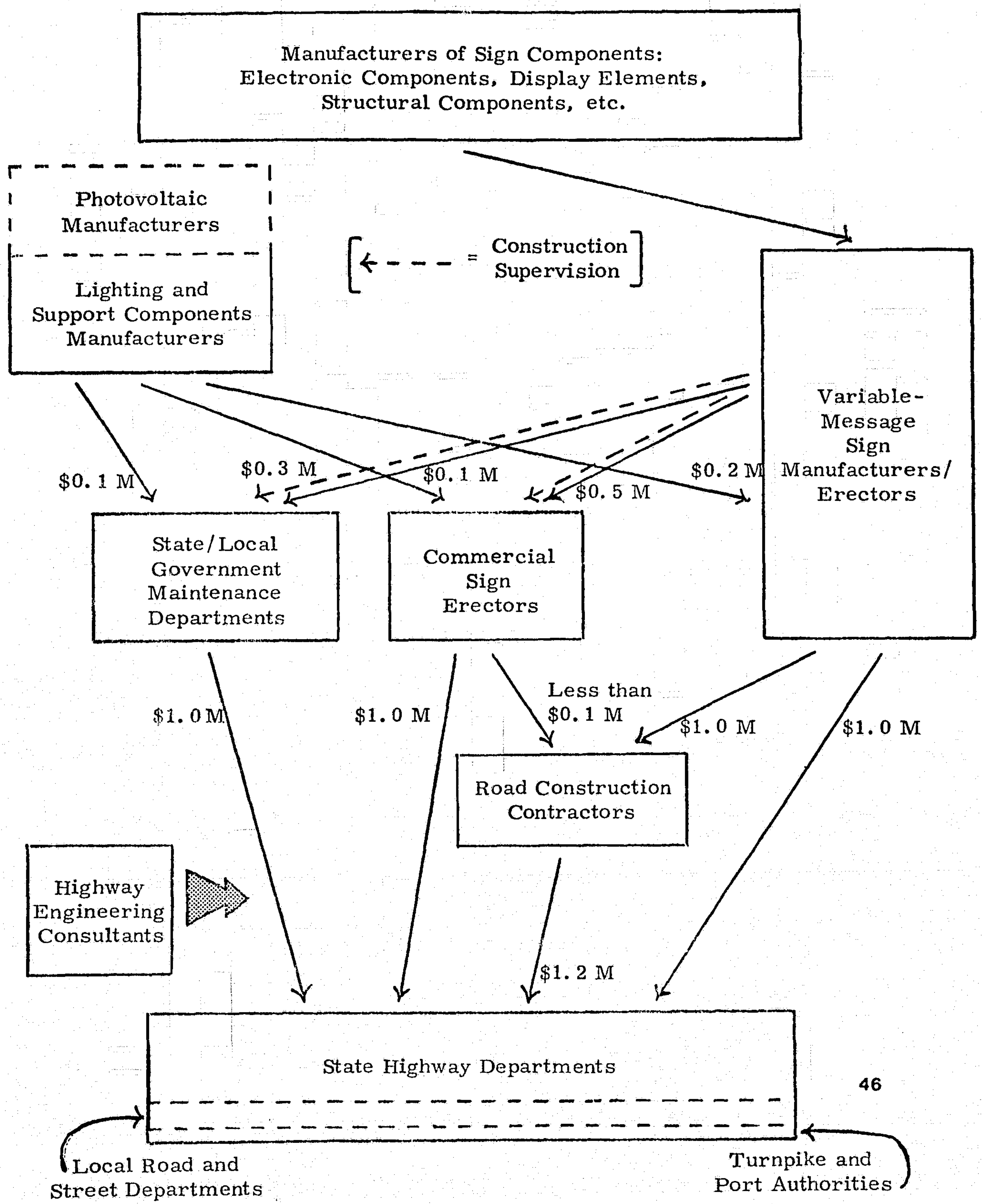


Exhibit 18

FLOW OF FIBER-OPTIC SIGNS AND COMPONENTS WITH ESTIMATED VALUE OF MATERIALS ON EACH PATH IN 1977

(M = Millions)

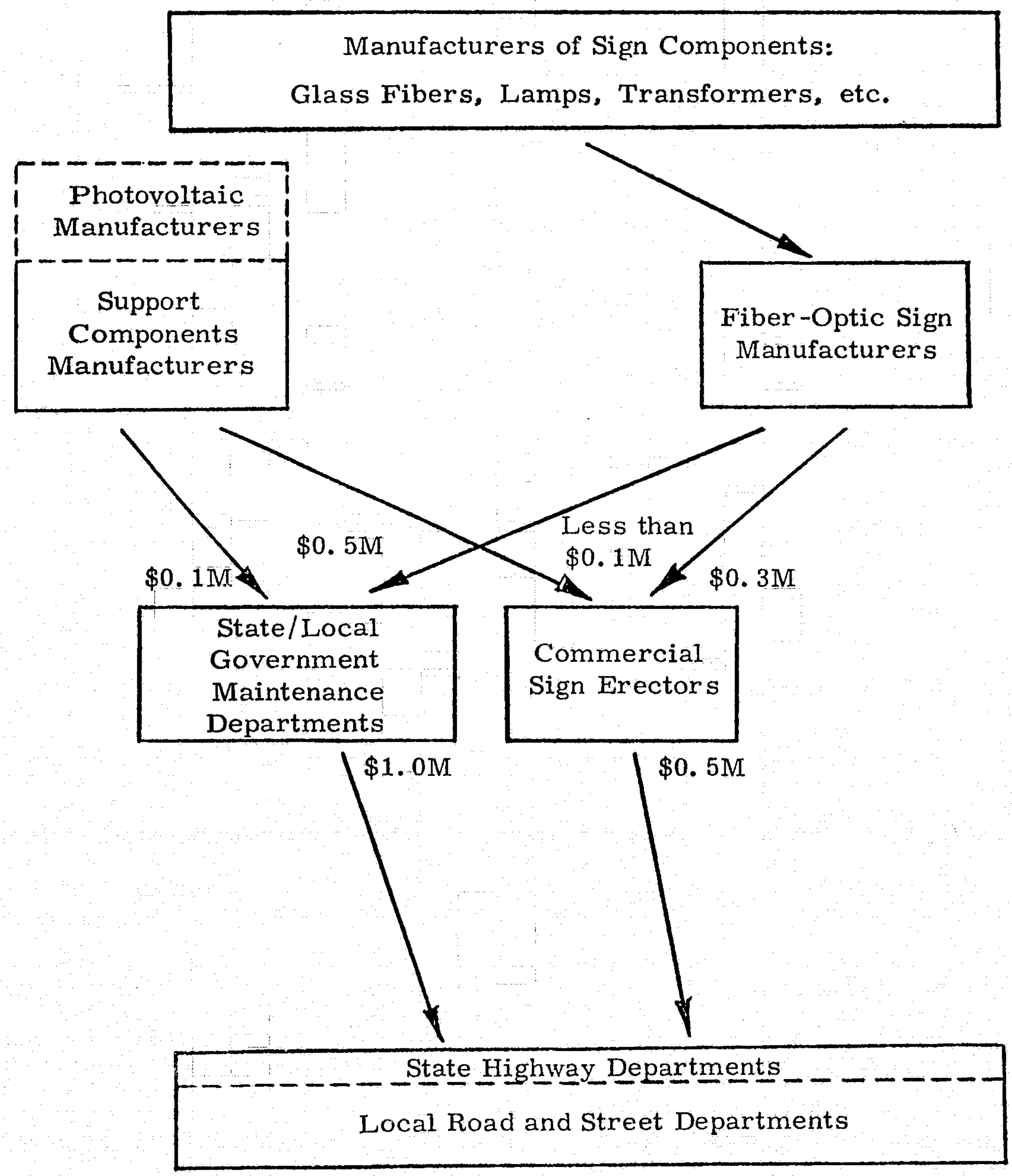


Exhibit 19

DESCRIPTIONS OF PRINCIPAL MANUFACTURERS AND ERECTORS OF HIGHWAY SIGNS

MANUFACTURERS

1. California Metal Enameling Company, Los Angeles, California

   Range of Products: Porcelain enameled static highway and advertising signs (suitable for use only where externally illuminated), building panels, electric water coolers.

   Total Sales: \$5-million

   Estimated Sales of Highway Signs: \$3-million

   Nature of Sales Organization: Direct company salesmen

2. Crouse-Hinds Company, Syracuse, New York

   Range of Products: Traffic control products (including fiber-optic pedestrian signals), electrical construction and safety materials, electrical distribution apparatus, commercial and industrial lighting.

   Total Sales: \$250-million

   Estimated Sales of Fiber-Optic Signs: \$375,000

   Nature of Sales Organization: Traffic control products distributors

3. Ferranti-Packard, Ltd., Telespot Systems Division, New York, New York

   Range of Products of Parent Company: Variable message signs and components, information displays, inventory control systems, power transformers, electric distribution apparatus.

   Total Sales of Parent: \$55-million

   Estimated Sales of Variable Highway Sign Systems: \$400,000

   Nature of Sales Organization: Direct company salesmen

4. Lyle Signs, Inc., Minneapolis, Minnesota

   Range of Products: Static highway signs, signs for industrial companies and airports.

   Total Sales: \$6-million

   Estimated Sales of Highway Signs: \$4-million

   Nature of Sales Organization: Direct company salesmen

5. <u>3M Company, Traffic Control Products Division</u>, St. Paul, Minnesota

Range of Products of Parent Company: Abrasives, adhesives, chemicals, electrical products, health care products, recording materials, tape and allied products, static controls, nuclear products.

Total Sales of Parent: $3.5-billion

Estimated Sales of Variable Highway Signs: $500,000

Nature of Sales Organization: Direct company salesmen

6. <u>Valtec Corporation</u>, West Boylston, Massachusetts

Range of Products: Fiber-optic lamps, cable, components, and traffic signals; piezoelectric products; precision optical components.

Total Sales: $31-million

Estimated Sales of Fiber-Optic Traffic Signals: $375,000

Nature of Sales Organization: Traffic control products distributors

7. <u>Ve-Ped Traffic Controls, Inc.</u>, Oklahoma City, Oklahoma

Range of Products: Manufactures and distributes flap-type variable message signs and traffic signal support hardware; also distributes traffic signals and other traffic controls.

Total Company Sales: $4-million

Estimated Sales of Flap-Type Signs: $500,000

Nature of Sales Organization: Use company salesmen within own territory; elsewhere, sell through traffic control products distributors.

INTEGRATED MANUFACTURERS AND ERECTORS

1. FOSCO Fabricators, Inc., Dixon, Illinois

   Range of Products: Highway signs, including lamp-matrix, disc-matrix, drum, and scroll variable-message signs; directional, regulatory, warning, and other static signs.

   Total Company Sales: $13-million

   Estimated Sales of Highway Signs: $13-million

   Nature of Sales Organization: Direct company salesmen

2. Hubbell Highway Sign Company, New Hartford, New York

   Range of Products: Directional, regulatory, and warning signs, guard rails, fences, and roadway lighting.

   Total Company Sales: $8-million

   Estimated Sales of Highway Signs: $4-million

   Nature of Sales Organization: Direct company salesmen

3. Mike Hunter, Inc., Forest Park, Georgia

   Range of Products: Directional, regulatory, and warning signs, guard rails, signals, and lighting.

   Total Company Sales: $11-million

   Estimated Sales of Highway Signs: $5-million

   Nature of Sales Organization: Direct company salesmen

4. Interstate Highway Sign Company/Interstate Sign Erectors, Inc., Little Rock, Arkansas

   Range of Products: Directional, regulatory, and warning signs, guard rails, and fences.

   Total Sales, Both Companies: $12-million

   Estimated Sales of Highway Signs: $9-million

   Nature of Sales Organization: Direct company salesmen

5. Winko-Matic Signal Company, Avon Lake, Ohio

Range of Products: Variable-message highway signs and flashing signals.

Total Company Sales: $2-million

Estimated Sales of Highway Signs: $0.6-million

Nature of Sales Organization: Direct company salesmen

ERECTORS

1. Whitmyer Brothers, Inc., Hammonton, New Jersey

Range of Products: Advertising and highway signs, guard rails, fences, and lighting.

Total Company Sales: $10-million

Estimated Sales of Highway Signs: $3-million

Nature of Sales Organization: Direct company salesmen

ESTIMATED MARKET SHARES OF ERECTORS OF HIGHWAY SIGNS IN 1977

(M = Millions)

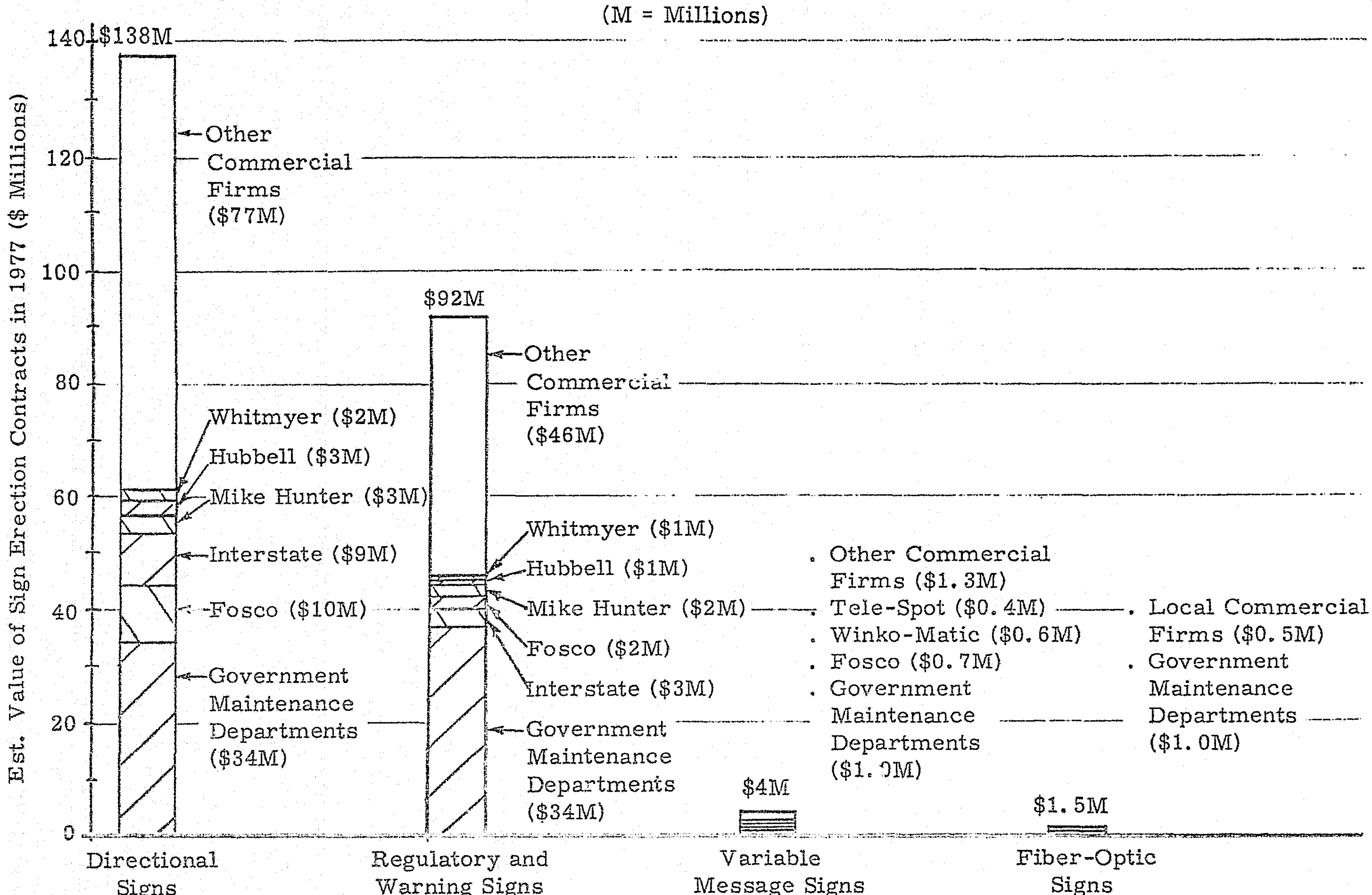
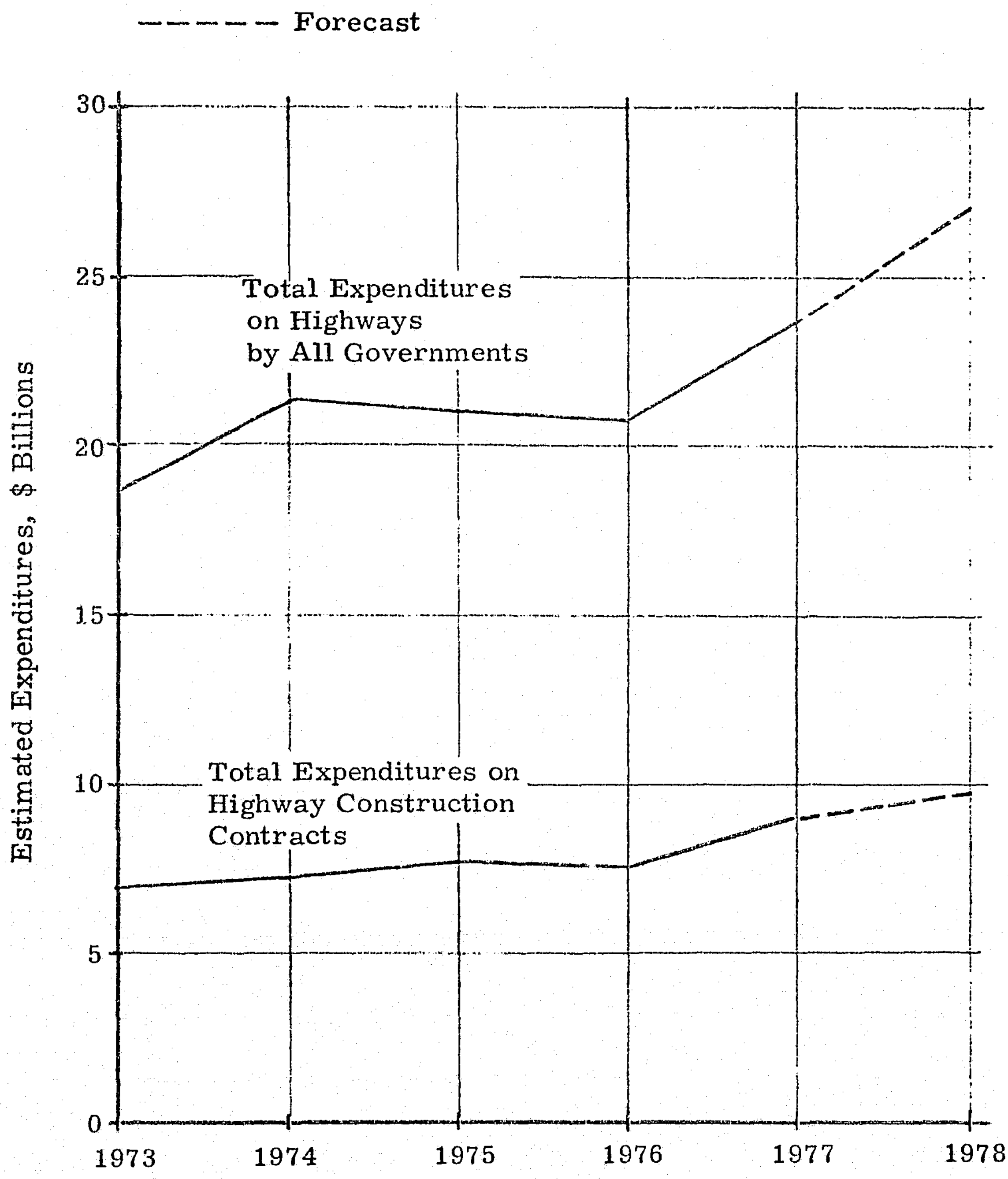


Exhibit 20

Exhibit 21

FIVE-YEAR HISTORY OF GOVERNMENT EXPENDITURES ON HIGHWAYS



Sources: DOT; McGraw-Hill

Exhibit 22

EXCERPTS FROM INTERVIEWS: COMMENTS ON SOLAR POWER FROM THE HIGHWAY SIGN INDUSTRY

A. Interviewees in the sign industry exhibit interest in solar electric power and optimism concerning its future.

"He suspects that the states would all jump at the chance to use photovoltaics if they had the opportunity. The use of solar power has great public relations value, and 'highway departments are all pretty political.'" American Sign and Indicator Corporation, Mr. Novak

"When I explained that we are doing this study to see how photovoltaic cells could best be applied, Ron said that he would be very interested in working with a photovoltaic manufacturer. Surprisingly, even though I explained that photovoltaic cells were usually justifiable economically only when the device to be powered is a considerable distance from the nearest power line, he still thought that the most attractive potential use would be in powering shopping center signs." Baker Electrical Products, Inc., Ron Akrid

"The majority of Skyline's variable message signs have been installed in rural, mountainous areas, because their primary use has been to warn motorists of road conditions in the mountains. He added that they have talked to some people in the Kansas Department of Transportation about the possibility of making signs to warn motorists of high wind conditions or of ice on bridges, and both of these types of signs would probably be located in rural areas also. Therefore, Bob was quite interested in the idea of using photovoltaics to power his signs." Skyline Products Company, Bob Stadjuhar

"When I told Lou that we were looking for good markets for applying photovoltaics to electrified signs, he waxed enthusiastic. He believes that there are probably quite a few possible remote sign locations where photovoltaic power would be eminently suitable, primarily in the mid-west and west and probably most often with railroad crossing signals. Lou emphasized that they would be very happy to work in cooperation with a photovoltaic manufacturer on fiber optic signs, and he invited us or any representative from a photovoltaic manufacturer to come out to talk to him about the subject any time." Valtec Corporation, Lou Iadarolla

B. Nevertheless, it is observed that variable message signs, which are especially well-suited to solar operation, are seldom located far from utility power.

"Given its high cost, photovoltaic power probably would be desirable only in cases where the variable message sign was to be located some distance from commercial power lines. In his own experience, variable message signs are almost never located outside of downtown areas. In fact, he could only think of one or two they have been involved with which were in rural areas. The majority of variable message signs are sold for warning motorists of traffic conditions, which means that they are almost always installed on expressways in downtown areas." Fosco Fabricators, Inc., Subsidiary of Michigan General Corporation, Tom Duffy

"In investigating variable message signs as an application for photovoltaic power, I inquired if many were installed at some distance from commercial power lines. Bill said that the only installations he knew about where the sign was installed at a considerable distance from existing power lines were the signs used in conjunction with truck weighing stations." Ve-Pad Controls, Inc., Bill McCurdy

C. Furthermore, sign manufacturers feel that they are in no position to propose alternative power sources to the various state highway departments. Instead, they are compelled to bid on the signs precisely as specified by the state.

"A highway department would never buy and install a solar power supply itself for use with a variable message sign, since they almost always want 'turn-key' projects where one contractor is responsible for everything. If a state wanted a VMS which would be powered by photovoltaics, it would simply put that into the specification. Then, it would be up to AS&I to buy the solar power supply and assemble it together with the sign, which they would want to do anyhow just to make sure that the two were compatible." American Sign and Indicator Corporation, Mr. Novak

"I asked if it was common for them to propose a set of specifications different from those spelled out in the request for bids sent to them by the states. Tom said that this is simply not done. Tom apparently had never considered sending in two bids, one based on the state's specifications, and the other based on an alternate set. He believes that this practice might be illegal. If they bid on a different set of specifications, and were the low bidder, he claimed that the state would expect them to supply everything that had been laid out in the state's specifications at the price which they had bid, regardless of which specifications that bid had been based on. Therefore, Fosco would lose money. At any rate, Tom would certainly not want to hurt Fosco's chances of winning the contract by stirring up the waters." Fosco Fabricators, Inc., Subsidiary of Michigan General Corporation, Tom Duffy

D. Hence, in the opinion of the sign industry, the initiative in introducing solar power must be assumed by the states, responding, perhaps, to sales incentives offered by the photovoltaic industry.

"He believes that the initiative in using photovoltaics has to come from the states themselves, or the promotional efforts of the photovoltaic manufacturers, rather than efforts by AS&I, since, by the time the request for bids gets to AS&I, the specifications are usually unchangeable." American Sign and Indicator Corporation, Mr. Novak

"State highway departments are notoriously reluctant to try anything new. Therefore, the best way to sell solar power for highway uses is for the photovoltaic manufacturers to do primary selling to the design sections of the state highway departments. They are the ones who either write or approve the specifications for variable message signs, and so they are the people who have to be convinced. Perry said that approximately 90% of Fosco's business comes ultimately out of those sections." Fosco Fabricators, Inc., Subsidiary of Michigan General Corporation, Perry Sommer

Exhibit 23

COMPARISON OF TYPICAL COSTS OF TYPES OF HIGHWAY SIGNS AND PHOTOVOLTAIC POWER SUPPLIES REQUIRED

(Signs are Assumed to be Located Near St. Louis, Missouri)

Type of Sign	Average Power Required	Est. Cost of Sign and Components	Est. Cost of Installation	Total Sign Cost	Est. Cost of Photovoltaic Supply
Directional	117W	$1,350	$1,550	$2,900	$32,100
Regulatory and Warning	72	78	112	190	19,500
Variable Message:					
Disc-Matrix and Drum Types	93	50,000	50,000	100,000	24,900
Flap-Type	20	600	600	1,200	5,240
Fiber-Optic	42	230	200	430	11,500

VII. APPROACHES TO HIGHWAY DEPARTMENTS IN SELECTED STATES

A. Solar Electric Power as a Standard Product

Over the course of this program, TMA's attitude toward the marketing of solar electric power supplies for highway applications has evolved considerably. At the time of the preparation of the first proposal for this project, it was presumed that potential highway-related uses for solar electric power would consist of a series of separate applications which could be analyzed separately. It would then follow that the introduction of solar electric power would proceed most rapidly in those applications which the study showed to be most promising. Nevertheless, as more information was compiled, it began to appear questionable whether, from the standpoint of a potential supplier of photovoltaic power supplies, there were any significant differences whatsoever between applications. In fact, it appeared that the line of equipment which the manufacturer would need to offer would be essentially the same for all highway-related applications. The manufacturer would have to know the equivalent continuous wattage consumed by the electrical load, the voltage at which it could be driven, and the environmental conditions resulting from its geographic location, but he need not be concerned whether the driven device was a sign, or a light, or an instrument.

Thus it began to appear that the cause of solar electric power would be furthered most if the various state highway departments could be made informed about the capabilities and costs of photovoltaic power supplies in general, in the hope that the states would then become interested in using solar power for any and all applications which might prove appropriate. To this end, therefore, it was agreed that TMA representatives would visit personally a number of the state highway departments in order to review their power requirements in situations where a solar electrical system might prove advantageous, and to discuss the specifications and costs of appropriate solar electric power systems so as to facilitate comparison with other power sources already familiar to the state.

B. Preparation of a "Solar Electric Power Handbook"

Earlier contact had already made it apparent that in all but a handful of states, the highway departments were almost totally unfamiliar with photovoltaic equipment. In anticipating detailed discussions with the highway departments in some of these states, need was immediately recognized for a means to acquaint highway officials quickly with the capabilities of solar electric power systems, as well as a means to determine quickly their approximate specifications and cost. Until this information could be generated, comparisons with conventional sources of power would be difficult and time-consuming. Furthermore, in cases where solar electric power might emerge as the preferable alternative, the state would then need guidance as to how to specify solar power for actual purchase.

A handbook was therefore prepared which provides the following information:

(1) A summary of typical power consumption of highway-related devices (Exhibit 24).

(2) A format for the calculation of equivalent continuous load (Exhibit 25).

(3) A tabulation of appropriate power supply voltages for typical highway-related loads (Exhibit 26).

(4) A map of the United States giving references for the sizing of both photovoltaic generators and batteries (Exhibit 27).

(5) Sizing tables for photovoltaic arrays and batteries (Exhibits 28 and 29).

(6) Charts giving approximate 1978 prices for photovoltaic generators, batteries, and inverters (Exhibits 30, 31, and 32).

(7) Illustrations of sizing (Exhibit 33) and of pricing (Exhibit 34) solar power supplies.

In addition to the foregoing, the handbook incorporates considerable background information and a sample specification for a complete photovoltaic power supply. Although the examples discussed in the handbook are all highway-related, the information presented therein can readily be adapted for solar applications of many other types.

Copies of this handbook have been provided separately to NASA.

C. Selection of State Highway Departments for Meetings

In choosing states for detailed discussions, three sets of factors were considered:

(1) The number of installations which the state expected to make over the next five years in classes of apparatus for which solar electric power is appropriate, where the installation was expected to be more than one-half mile from utility power.

(2) The number of such installations in types of application which rank high in the evaluation performed as a part of the first phase of this study.

(3) Willingness of the representatives of the state to meet with TMA, as well as mutual convenience in arranging such an appointment.

The states eventually selected for such meetings were Maryland, North Carolina, California, Illinois and Massachusetts.

D. Results of Discussions

Although in all five states the highway department appeared to be pleased to have a copy of the Solar Electric Power Handbook, reactions to the potential application of solar power differed considerably from one state to another. The results may be summarized as follows:

(1) Maryland. Having installed 50 solar-powered motorist aid call boxes several years ago, Maryland is one of the few states which has first-hand familiarity with solar electric power. Maryland's reaction to this initial installation is not entirely favorable, however, since the photovoltaic equipment has required an unexpected amount of cleaning and maintenance to keep it operating reliably.

Since Maryland is heavily built up, there are very few highway locations within the State which are more than one-half mile from utility power. In addition, few electrical installations are planned where the equivalent continuous electrical load will be less than 100 watts.

Previous comments that the State expected to install a number of directional signs requiring less than 100 watts proved to be inaccurate; the lighting used by Maryland for directional signs actually consumes more than 1 kilowatt per sign during the hours of darkness.

As a result, the most appropriate prospective installations for solar power appear to be those for monitoring and controlling the flow of traffic on beltways located in the area around Baltimore. Power line extension for the monitoring instruments has been found expensive by the State since the new power cables must be buried, and it is frequently necessary to purchase a right-of-way when the power line must pass through private property.

Despite these problems, comparison indicated that solar electric power would have little opportunity to be cost competitive in this type of installation. The most that Maryland has had to spend to provide utility power for a traffic monitoring installation has been approximately $5000, with $2500 a more typical figure. The equivalent continuous power drawn by such a traffic monitoring installation is approximately 100 watts, and, for the area around Baltimore, the 1978 cost of a suitable solar power installation would be approximately $30,000. Even if allowance is made for future reductions in the cost of photovoltaic equipment, it does not appear that solar electric power could be competitive for this type of installation in the foreseeable future.

(2) <u>North Carolina</u>. The North Carolina Department of Transportation has had no experience with solar electric power whatsoever. Two applications were discussed here with the Traffic Engineering Section: lighted warning signs situated at points where fatal accidents have occurred, generally on mountain roads in the western part of the State; and ice warning instruments which could be located on bridges in any part of the State. On first exposure, neither application appeared attractive for solar electric power.

In the case of warning signs, a typical installation uses a pair of 116-watt beacon lights which flash alternately under the control of a 10-watt flasher. In one recent installation, the power line to operate such a sign was extended approximately 1.5 miles at a cost of $5200. A solar electric power system to operate the same sign at this location would have cost approximately $34,000.

In the case of ice detecting installations, the economic outlook for solar electric power appeared even less favorable. Although the detecting instrument itself draws only about 25 watts, the instrument controls a pair of beacon lights identical to those described above, so that the equivalent continuous load imposed by the installation can run at a level of approximately 150 watts for long periods of time. Hence the cost of a suitable solar electric supply would be at least $40,000, whereas the detectors, of which two have been installed already and two more are planned, are no more than one mile from the nearest utility power.

As a result of these difficulties, a subsequent conversation was held with the highway officials here to get their reaction to the possible substitution of DC-operated strobe lights in place of the beacon lights which are used today. The advantage in the use of strobe lights would be the reduction of the equivalent electric load to less than 10 watts, which would then bring the cost of the solar system down to approximately $3000. At this level, solar power would be highly competitive with the cost of extending utility power.

This suggestion, however, met with the immediate objection that the "Manual of Uniform Traffic Control Devices," which is published by the Federal Highway Administration, does not recognize the use of strobe lights for warning purposes. As a result, strobe lights could not be used on projects for which Federal funding has been requested, which would include all of the State's proposed ice detection instruments, and some of its warning signs. In addition, it was mentioned that the State has used a small number of strobe lights in non-critical applications which are entirely State funded, but has found their level of reliability to be poor. Thus it appeared to the highway engineers that even if solar-powered strobe lights were used in some applications, on the grounds that their first cost was lower than that of extending the utility power line, this saving might later be dissipated by the increased need for maintenance and replacement.

Overall, therefore, no opportunities were found for solar power which appeared attractive enough to motivate the State to specify it.

(3) Massachusetts. Detailed discussions were conducted in this state with both the Traffic Engineering and the Planning & Development sections of the Bureau of Transportation. In the case of the Traffic Engineering Section, discussion centered around six variable-message signs which are to be installed along an interstate highway leading into Boston. Although the signs are located in urban areas, they would have to be operated by power lines which would run for a considerable distance in underground conduit. Although the equivalent continuous load imposed by such a sign is extremely small (roughly 1 watt), and the estimated cost of a solar power installation would only be about $1400, this still proved to be a higher cost than the State would expect to pay for the extension of utility power.

At the Planning & Development Section, interest focused on the installation of permanent traffic recorders. In this case, calculation indicated an equivalent continuous load of less than 1 watt per recorder, so that a solar electric power installation would cost approximately $530. Were such a permanent traffic counter to be installed where utility power had to be brought to it, the total cost to the State, including an allowance for the present value of minimum electric power charges for some 20 years into the future, would run anywhere from $960 to $6600, depending upon the location. In this application, therefore, it appeared that a solar electric power installation could offer an appreciable saving.

Despite these comparisons, the interviewees in both sections of the Bureau of Transportation left no doubt that they would not recommend the use of solar power, nor would they install it unless required to do so by higher authority. In each case, the reason given was that the long-term savings resulting from the use of solar energy, if any, would not be sufficient to justify the risk involved in using a new and untried source of power, and that such savings would not accrue to the Bureau of Transportation anyway. It appeared, therefore, that until such time as the members of this Bureau become convinced that photovoltaics are a dependable and risk-free power source, serious interest in solar electric power would require persuasion from some source outside of the Bureau of Transportation, or a much stronger economic incentive.

(4) Illinois. Discussions with the Department of Transportation in this state proved to be fortuitous, since funds were recently appropriated to this department for an experimental application of solar power. The officials of this department are essentially unfamiliar with solar electric systems, and hence were especially happy to obtain the fundamental application data contained in the handbook turned over to them by TMA.

The Department's goal is to have a highway-related solar power installation operating no later than July 1979. Applications under consideration include a drum-type variable-message sign, a height monitor, a following-too-closely monitor, an ice detector, and a traffic counter.

One prospective installation which was discussed in considerable detail involved a truck height monitor, to be installed near Kankakee. The monitor proposed was a model with which TMA was already familiar, which has an equivalent continuous power consumption of 95 watts. The total equipment cost for a solar electric power system to operate this monitor in Kankakee, according to the Solar Electric Power Handbook, would be approximately $34,000. This figure surprised the representatives of the Transportation Department, since they had had the impression that solar power would cost much less than that. While such an installation may prove satisfactory for demonstration purposes, the officials felt that it was unlikely to make economic sense in Illinois during the near future, since the typical cost for extension of a power line in that state is approximately $1.50 per foot.

Nevertheless, it appears that at least one highway-related solar electric power installation will be made in Illinois, and that this experience is likely to intensify the Department of Transportation's interest in this technique.

(5) California. Although the State of California has probably purchased more solar electric power equipment than any other state in the union, none of it has been bought so far by the California Department of Transportation. Instead, the purchases have been made by the State's General Services Department, which has used the equipment mainly to power various types of radio stations. Hence TMA arranged for representatives of both departments to meet together to discuss potential applications in connection with the State's highways.

Highway-related applications for solar power have received considerable preliminary investigation within the State already, and the State has submitted applications to the U. S. Department of Energy for grants covering several photovoltaically-powered projects. These can be summarized as follows:

(a) At present California has some 460 battery-powered ice detectors, with associated warning signs, located on highway bridges. The purpose of the first proposed grant, therefore, would be to demonstrate the feasibility of using solar power to replace these batteries, which must be renewed at a cost of $50 to $60 per sign per year. As proposed, the warning signs would be lighted only with strobe lights, so that each detector installation would impose an equivalent continuous power requirement of no more than about 7 watts. Even in the relatively adverse climate of Northern California, a suitable solar electric power supply would cost only $2000 at 1978 prices, and the State appears to consider such a substitution worthwhile.

(b) The State's second proposal is to use solar power to light a small warning sign which would consume about 175 watts when illuminated, or an average equivalent continuous load of somewhat less than 100 watts. The solar electric power for such a sign would cost about $24,000 today in Northern California, which would be the equivalent of extending the utility power line in that territory approximately 2.5 miles. The State feels that it will have little difficulty in finding an appropriate location for such a sign situated at least that far from the nearest utility power.

(c) The third application proposed is for cathodic corrosion protection of a highway bridge in the Salton Sea area, near the Mexican border. Although the protection of highway bridges from corrosion is a problem of tremendous economic significance to all state highway departments, the cathodic protection system on which California has been working is still highly experimental. Although early tests indicated that effective protection for an average-sized two-lane bridge could be secured at an equivalent power level far less than 50 watts, later work makes it appear that a power of several hundred watts will be required instead. If these latter readings are confirmed by further work, it appears that few instances will be found in which solar power will be economically preferable to the extension of utility power. Nevertheless, this class of application is potentially huge, and certainly warrants continued interest.

Overall, the impression was gained that the State of California has an excellent understanding of the capabilities, costs, and proper applications for solar electric power, and that the State can be counted upon to use its own initiative to seek out and develop new applications wherever they prove to be appropriate.

Exhibit 24

SUMMARY OF TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

	Est. 24-Hour Average Load
1. Lighting	
(a) Area Lighting with High-Pressure Sodium Lamps	
(1) Expressway Interchange (one luminaire	276 watts
(2) Rural Road Intersection	70
(b) Navigation Light System on a Bridge	210
2. Signs	
(a) Warning or Regulatory Sign with Beacons	72
(b) Fiber Optic Sign	42
(c) Variable-Message Signs	
(1) Lamp Matrix Type (small)	6300
(2) Disc Matrix Type (small)	93
(3) Drum Type	93
(4) Flap Type	20
(d) Overhead Directional Sign Illumination	117
3. Railroad Crossing Signals	
(a) Flashing Lights Only	13
(b) Flashing Lights with Gates	16
4. Radio Installations	
(a) VHF, UHF and Microwave	
(1) VHF or UHF FM Repeaters	19
(2) VHF or UHF Remote Base Station with Microwave Link	59
(3) Microwave Repeater	80
(b) CB Radio Repeater	80
(c) Travelers' Information Radio Transmitter	60
5. Cathodic Protection for Bridges	
(a) On Bridge Decks	500-800
(b) On Reinforced Concrete Footings	5-10

	Est. 24-Hour Average Load
6. Instruments	
(a) Traffic Counter, Permanently Located	0.19
(b) Speed Monitor	7.3
(c) Height Monitor	95
(d) Intervehicle Gap Monitor	168
(e) Fog Detector	300
(f) Ice Detector	120
7. Motorist Aid Call Box	0.04
8. Other Applications	
(a) Traffic Signals	
(1) Stop Lights (Minimum System)	260
(2) Four-Way Flashing Beacons	125
(b) Portable Barricade Flasher	0.17
(c) Roadside Rest Area (Rural)	17,000
(d) Outdoor Advertising Poster Panel	93

Exhibit 25

CALCULATION OF EQUIVALENT CONTINUOUS LOAD

Segment of Load	Load Characteristics: Load Watts		Percent of Full Operating Cycle		Contribution to Equivalent Load
1)		X		=	
+2)		X		=	
+3)		X		=	
+4)		X		=	
Total Equivalent Continuous Load					

Example: Determine the equivalent continuous load of a highway warning sign, equipped with two flashing lights, which operates at all times. Each light draws 67 watts on a "2-seconds-on 2-seconds-off" cycle. The lights are switched by a flasher which draws 5 watts continuously.

Segment of Load	Load Characteristics: Load Watts		Percent of Full Operating Cycle		Contribution to Equivalent Load
1) Light #1	67	X	50%	=	33.5 watts
+2) Light #2	67	X	50%	=	33.5
+3) Flasher	5	X	100%	=	5.0
+4)		X		=	
Total Equivalent Continuous Load					72 watts

Exhibit 26

POWER SUPPLY VOLTAGES FOR TYPICAL HIGHWAY-RELATED LOADS

Equipment	Suggested Voltage
I. Equipment Usually Convertible to DC Input	
A. Lighting	
Low-wattage area lighting	12 V DC
Bridge navigation lights	12 V DC
B. Signs	
Warning signs	12 V DC
C. Railroad Crossing Signals	10 or 12 V DC
D. Radio Equipment	
VHF and UHF repeaters	12 V DC
Microwave repeaters	48 V DC
CB repeaters	12 V DC
Travelers' information radio	24 V DC
Motorist aid call boxes	12 V DC
E. Cathodic Protection Equipment	24-60 V DC
F. Instruments	
Traffic counters	12 V DC
Speed monitors	12 V DC
Height monitors	12 or 24 V DC
Ice detectors	12 V DC
II. Equipment Likely to Require AC Input	
A. Signs	
Warning signs	120 V AC
Fiber optic signs	120 V AC
Variable message signs	120 V AC
Directional signs	120 V AC
B. Instruments	
Speed monitors	120 V AC
Height monitors	120 V AC
Gap monitors	120 V AC
Fog detectors	120 V AC
Ice detectors	120 V AC

Note: Some equipment appears in both the DC-convertible and non-convertible categories, depending upon size, type of display, or other specifications of the manufacturer.

SIZING FACTOR MAP

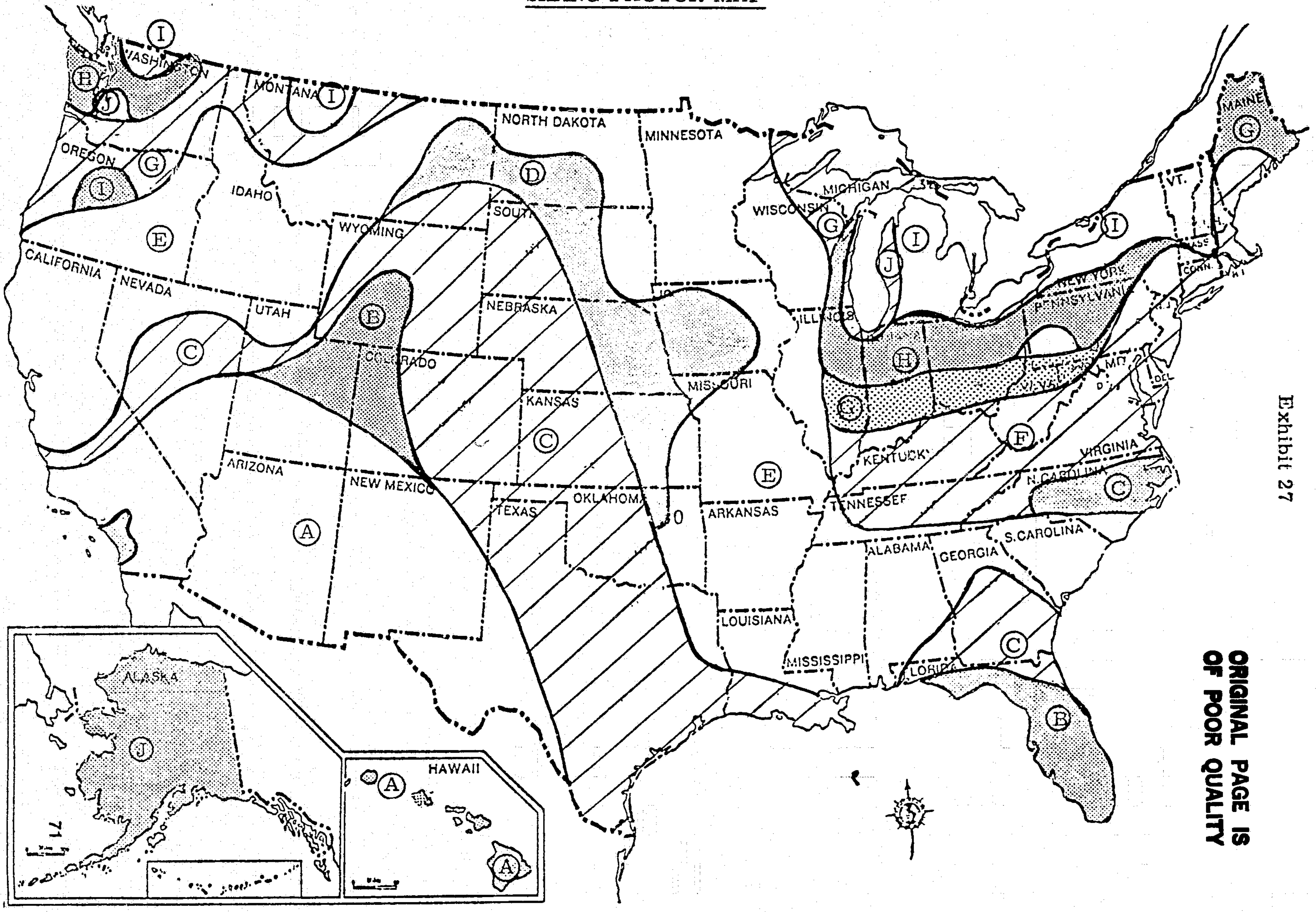


Exhibit 27

Exhibit 28

ARRAY SIZING TABLE

(Peak Watts)

Continuous Equivalent Load Wattage	Zone (From Sizing Factor Map) A	B	C	D	E	F	G	H	I	J
0.1	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0
0.25	1.25	1.5	1.5	1.75	1.75	2	2	2.25	2.25	2.5
0.5	2.5	3.0	3.0	3.50	3.50	4	4	4.5	4.5	5
1.0	5.0	6.0	6.0	7	7	8	8	9	9	10
1.5	7.5	9.0	9.0	10.5	10.5	12	12	13.5	13.5	15
3	15	18.0	18.0	21	21	24	24	27	27	30
4.5	22.5	27	27	31.5	31.5	36	36	40.5	40.5	45
6	30	36	36	42	42	48	48	54	54	60
9	45	54	54	63	63	72	72	81	81	90
12	60	72	72	84	8[illegible]	96	96	108	108	120
20	100	120	120	140	140	160	160	180	180	200
30	150	180	180	210	210	240	240	270	270	300
45	225	270	270	315	315	360	360	405	405	450
70	350	420	420	490	490	560	560	630	630	700
100	500	600	600	700	700	800	800	900	900	1000
140	700	840	840	980	980	1120	1120	1260	1260	1400
200	1000	1200	1200	1400	1400	1600	1600	1800	1800	2000
250	1250	1500	1500	1750	1750	2000	2000	2250	2250	2500
300	1500	1800	1800	2100	2100	2400	2400	2700	2700	3000

Exhibit 29

BATTERY SIZING TABLE

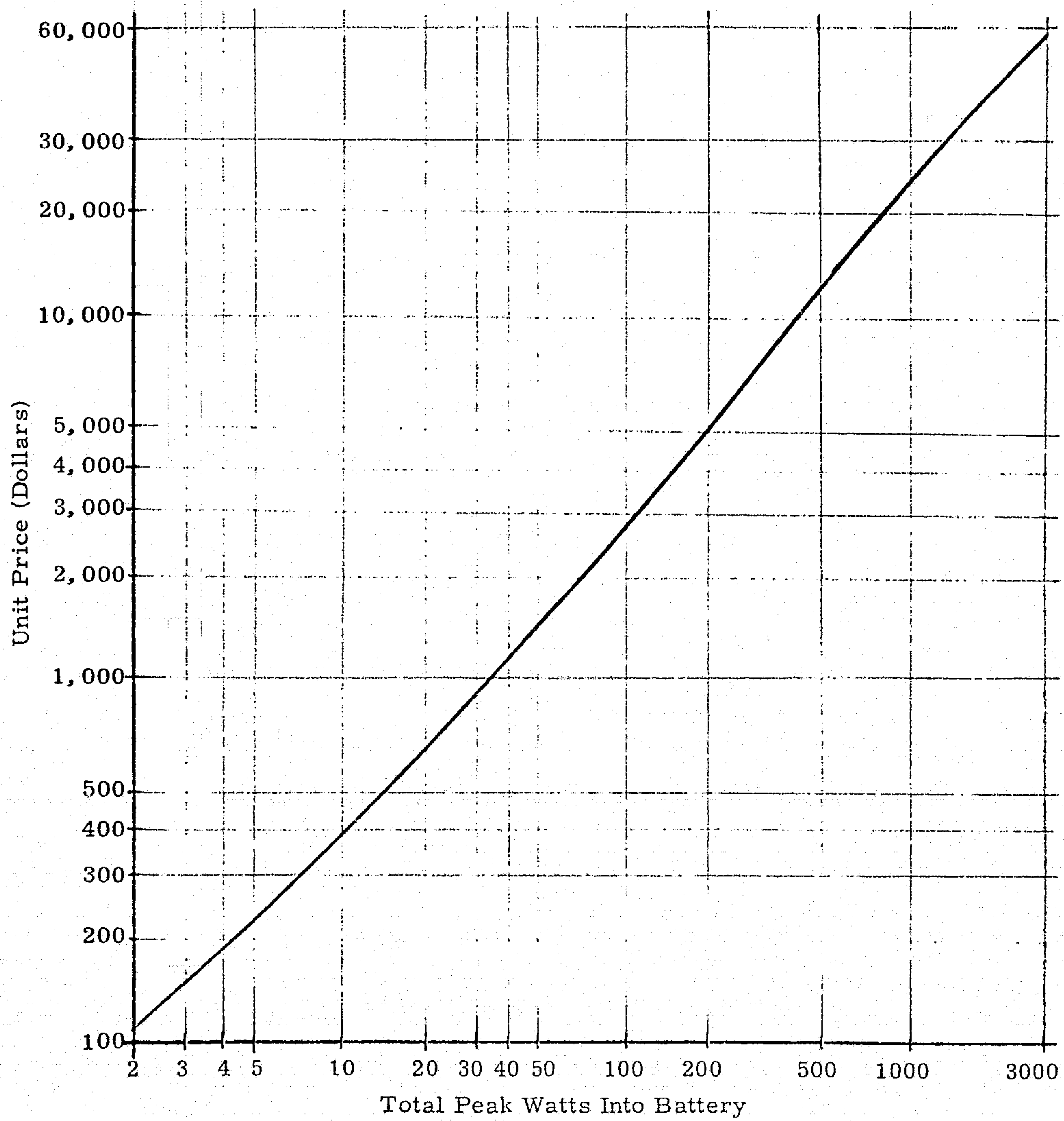
(Ampere-Hours for 12-Volt System)

Continuous Equivalent Load Wattage	Zone (From Sizing Factor Map) A	B	C	D	E	F	G	H	I	J
0. 1	2	2. 4	2. 9	3. 0	4. 4	4. 8	5. 8	6. 0	8. 0	13. 6
0. 25	5. 3	6. 3	7. 6	7. 9	11. 6	12. 6	15. 2	15. 8	21	36
0. 5	10. 5	12. 5	15	15. 8	23	25	30	31. 5	42	71
1. 0	20. 8	25	30	31	46	50	60	62	83	141
1. 5	31. 3	38	45	47	69	76	90	94	125	213
3	63	75	90	94	138	150	180	188	250	425
4. 5	94	113	135	141	206	226	270	281	375	638
6	125	150	180	188	275	300	360	375	500	850
9	188	225	270	281	413	450	540	563	750	1275
12	250	300	360	375	550	600	720	750	1000	1700
20	418	501	601	626	919	1002	1202	1253	1670	2839
30	625	750	900	938	1375	1500	1800	1875	2500	4250
45	938	1125	1350	1406	2063	2250	2700	2813	3750	6375
70	1458	1749	2099	2186	3207	3498	4198	4373	5830	9911
100	2000	2400	2900	3000	4400	4800	5800	6000	8000	13, 600
140	2918	3501	4201	4376	6419	7002	8402	8753	11, 670	19, 839
200	4175	5010	6012	6262	9185	10, 020	12, 024	12, 525	16, 700	28, 390
250	5200	6240	7488	7800	11, 440	12, 480	14, 976	15, 600	20, 800	35, 360
300	6250	7500	9000	9375	13, 750	15, 000	18, 000	18, 750	30, 000	42, 500

Exhibit 30

PRICES OF PHOTOVOLTAIC GENERATORS

- For 6 and 12 volt systems
- As of August 1978
- Prices apply to small quantity orders



ORIGINAL PAGE IS
OF POOR QUALITY

Exhibit 31

TYPICAL BATTERY PRICES

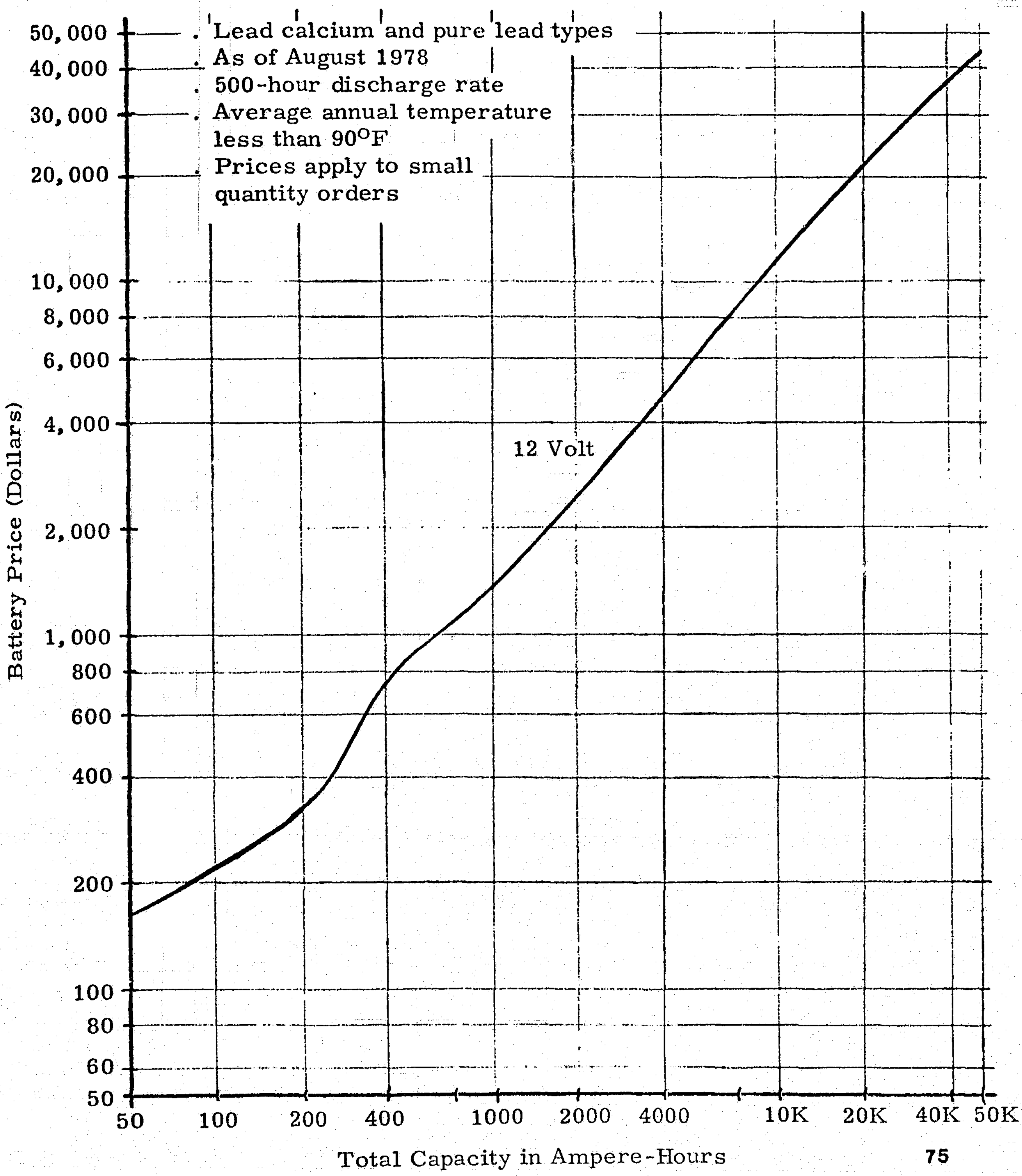


Exhibit 32

APPROXIMATE SMALL-QUANTITY PRICES FOR INVERTERS

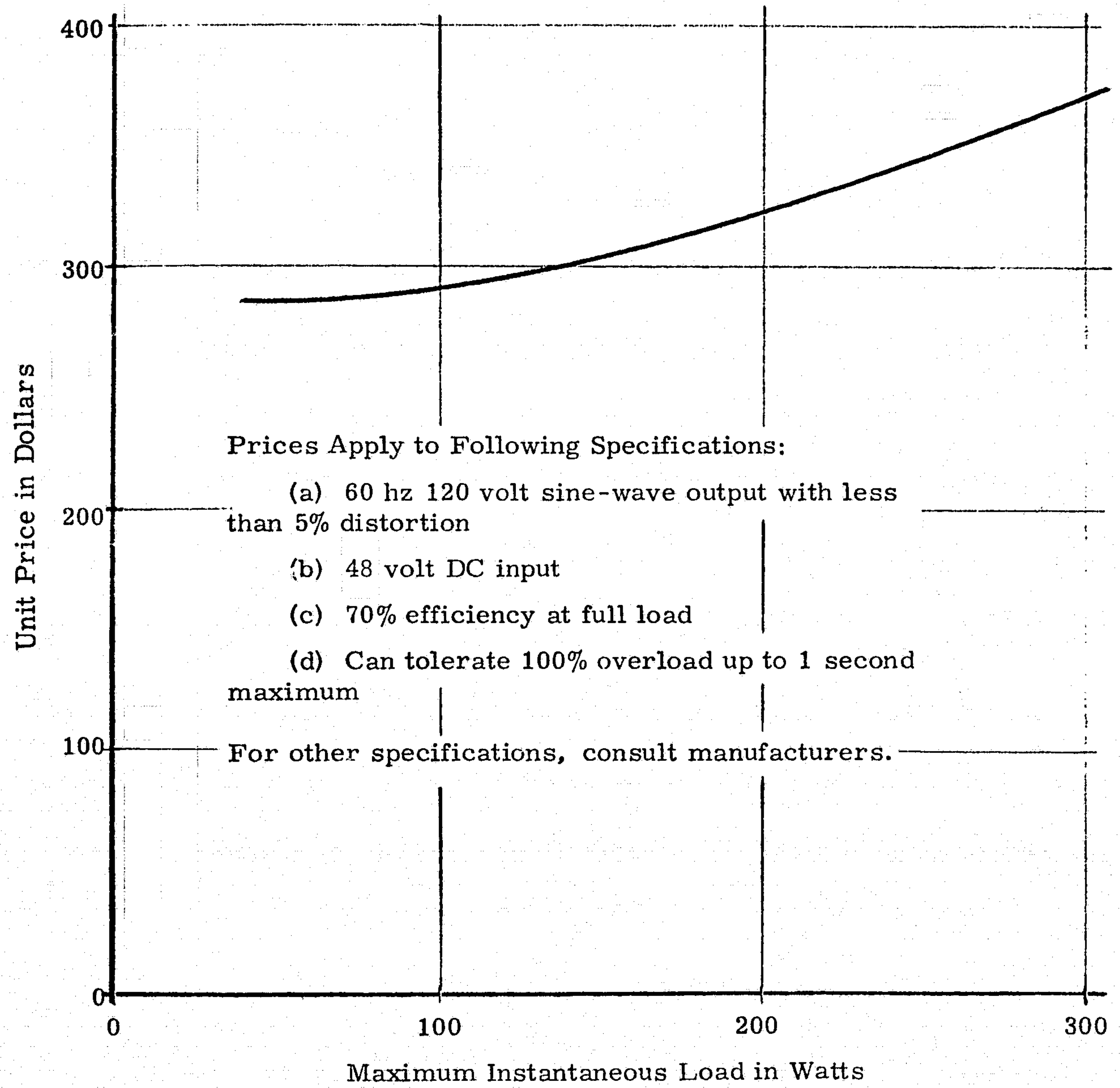


Exhibit 33

SAMPLE CALCULATION OF SIZE OF PHOTOVOLTAIC GENERATOR AND BATTERIES

Problem: To determine the size of the solar power equipment needed to operate a vehicle speed monitor, which is to be located near the southeastern corner of the State of Wyoming. The electronics in the monitor, which will operate continuously, consume 7 watts. The monitor has a display which will be triggered up to 100 times per day. When triggered, the display contains two 67-watt lamps which flash alternately for 20 seconds. The monitor must be operated from 60 hertz 120 volts AC.

Equivalent Continuous Load

Segment of Load	Load Watts		Percent of Full Operating Cycle		Contribution to Equivalent Load
Electronics	7	X	100%	=	7 watts
Display	67	X	2.3%	=	1.5
			Total		8.5 watts
			Add for losses in inverter (50%)		4.3
			Total		12.8 watts

Photovoltaic Generator Size

1. Referring to Exhibit 27, the equipment is to be located in Zone C.

2. Referring to the column for Zone C on Exhibit 28, and interpolating between the 12-watt and 20-watt entries, it appears that the photovoltaic generator for a 12.8-watt load should be rated approximately 77 peak watts.

Battery Size

1. Referring to Exhibit 29, for 12.8 equivalent continuous watts in Zone C, the battery would be rated approximately 384 ampere-hours at 12 volts DC.

2. Because this system is to drive the load through an inverter, however, a DC operating voltage of 48 volts is preferred. Hence the batteries should be rated 96 ampere-hours at 48 volts DC.

Inverter Size

1. The wattage rating of the inverter must at least equal that of the maximum instantaneous load (7 watts + 67 watts = 74 watts).

Exhibit 34

SAMPLE CALCULATION OF EQUIPMENT COST FOR SOLAR POWER SUPPLY

Problem: To estimate the cost of the equipment in the solar power system described in Exhibit 33.

Component	Method of Calculation	Approx. Cost	Reference
Photo. Gen.	From chart (77 pk. watts)	$2200	Exhibit 30
Batteries	From chart (384 amp-hrs)*	700	Exhibit 31
Inverter	From chart (74 watts)	290	Exhibit 32
Addl. Items	$6/pk. watt x 77 pk watts	462	
	Total estimated cost	$3652	

*Although this is a 48-volt battery, the ampere-hour rating of the 12-volt equivalent is used for pricing purposes.

Note: In this application, it has been assumed that the entire speed monitor, including its display, is to be driven through an inverter. It might have been possible, however, to convert the display to the use of DC lamps. Had this been done, both the wattage rating and the cost of the entire power supply could have been reduced by nearly one-third.

VIII. SUMMARY AND CONCLUSIONS

1. Because it is always possible to provide utility power to operate electrical equipment installed along a highway, solar electric power must always compete economically with utility power in order to win acceptance in any highway-related application. Other bases of economic comparison are of minor importance.

2. Analysis quickly indicates that the overwhelming elements in any such competition are first costs: the original cost of the solar electric power installation vs. charges for the extension of the utility power line.

(a) Since the first cost of a solar electric power system increases nearly in direct proportion to its continuous wattage capacity, whereas that of utility power depends only upon the length of power line extension, solar electric power will compare favorably to the extent that the wattage load is small, and the distance from existing utility power is great.

(b) Although they are minor factors in such competition, maintenance costs will tend to favor utility power, since the sum of monthly billing charges from the utility may be small compared to the periodic cost of replacing batteries for the solar power system.

(c) On the other hand, maintenance cost considerations will strongly favor both solar power and utility power when compared to other alternative power sources, such as engine generators, thermoelectric generators, and primary batteries.

3. A rough comparison of the total costs of utility vs. solar power indicates that solar power is unlikely to be competitive where the intended load consumes the equivalent of more than 100 continuous watts, or is situated less than one-half mile from the nearest existing power distribution. These criteria, however, must be considered as crude guidelines only, with exceptions possible on both sides.

4. Comparisons between utility power and solar power are affected surprisingly little by the location of the proposed installation or by reductions in the price of photovoltaic modules:

(a) For a given load, the "breakeven distance" for power line extension increases by only about 37% in going from the climate of Arizona to that of Washington State, for example.

(b) Because batteries and other "balance-of-system" costs are expected to change very little in the future, the same "breakeven distance" diminishes by less than 26% as the price of photovoltaic modules declines from their present level of around $11 per peak watt to the Department of Energy's target figure of $.50 per peak watt.

5. Almost all electrical installations which could be economically favorable to solar electric power are likely to occur along paved highways which are under the administrative control of state governments:

(a) Unpaved highways carry so little traffic as to require no electrical installations of any kind.

(b) No circumstances were found where highway-related commercial installations require less than 100 watts equivalent continuous load.

(c) Municipally maintained roads are seldom, if ever, over one-half mile from utility power.

(d) Contractors have few electrical loads which consume less than 100 watts. Such loads, when they occur, are generally portable devices, such as barricade flashers, for which a solar power supply is considered too large, heavy, expensive, and vulnerable to damage to be a practical alternative.

6. State highway departments, on the other hand, regularly install a variety of lights, signs, instruments, warning devices, and other equipment which consume the equivalent of less than 100 watts on a continuous basis:

(a) Surprisingly little of this equipment, nevertheless, is installed over one-half mile from utility power. The need for highway-related electrical equipment is generally a direct function of traffic density, and wherever traffic is heavy, utility power is usually readily available.

(b) Despite this, a detailed survey of state highway departments has indicated that installations in which solar electric power might be competitive have been occurring at an average rate of two or three installations per state per year, and are likely to continue to occur at about the same rate into the foreseeable future.

7. The class of application for which solar electric power appears best suited is highway signs, including lighted directional and warning signs, variable message signs, and fiber optic signs. Nevertheless, investigation also indicates that the highway sign industry cannot be expected to take the initiative in promoting the use of solar electric power in highway sign applications, for several reasons:

(a) The new business generated by association with solar power, if any, would be very small. Only a tiny fraction of the highway signs manufactured by this industry will be installed in situations where solar power could reasonably be considered. Such situations will occur, on the average, less than once per state per year.

(b) In most cases, the sign manufacturer or erector will be reluctant to assume the risks involved in providing a solar electric power supply, since the value of the power supply will far exceed the value of the sign.

(c) The sign manufacturer would normally propose a sign with solar electric power only if it were first specified by the state, since it is the tradition of this industry to respond only to state specifications, without taking exceptions.

8. For its part, the photovoltaic industry does not now appear ready to cultivate the state highway departments as a potential market either:

(a) Few photovoltaic manufacturers have field sales organizations extensive enough to maintain effective sales and service coverage of all state governments.

(b) Even where large distributor or representative organizations exist, they have had little reason to contact state governments. With a few notable exceptions (such as California and Arizona) the states have so far made no significant purchases of photovoltaic equipment.

(c) State highway departments are presently viewed by the photovoltaic industry as small and infrequent potential purchasers, handicapped by scant familiarity with photovoltaic equipment, whose orders are therefore likely to become unprofitable because of costly application engineering and after-sale service.

(d) Nevertheless, TMA estimates that situations where solar electric power could compare favorably with utility power are likely to occur at a rate of about 100 per year nationwide. Were all of these highway applications converted into sales of solar electric power equipment, the total market created would be of the order of $2-million per year.

(e) Therefore, were it to be demonstrated that this potential market was being converted into actual sales volume, the attitude of the photovoltaic industry could doubtless be changed very rapidly.

9. Hence the highway departments of the various states become the key to the development of the highway market for solar electric power:

(a) In cases where solar electric power compares favorably with other sources of power, the state itself will be the primary beneficiary of whatever economic savings will result.

(b) Few states have any appreciation of what these savings can be. At the present time, solar electric power is so little understood that only a handful of states are giving it any consideration as an alternative power source, and few of those understand its actual capabilities and costs.

(c) In addition, the adoption of solar electric power by the states will be retarded, as any new technology is, by fear of the unknown and reluctance to risk large appropriations on an unproven technique, especially where there are implications for highway safety.

10. Hence, to a considerable degree, the stimulation of a highway market for solar electric power requires "priming of the pump." The functions most needed to stimulate this market are:

(a) Education of state highway departments concerning the performance, specifications, and pricing of solar electric equipment, as well as assistance in identifying suitable applications for solar power.

(b) Reduction in the cost of first solar electric power installations, so as to provide incentive adequate to offset the risks inherent in adopting a new technology, and so as to give the state familiarity with and confidence in this new technique.

11. In the absence of other candidates, the "pump priming" function will probably have to be assumed by NASA and/or the Department of Energy, although the need to provide such a function is judged to be temporary. Once an appreciable sales volume is cultivated, momentum should be sustained thereafter by the normal working of the market.

12. Nevertheless, NASA and the Department of Energy must view this opportunity in perspective. It seems obvious that the prospective savings in fossil energy sources to be expected from highway-related solar applications are trivial. Whether an investment in the development of this market is justified, therefore, is a difficult question which goes beyond the scope of this investigation.

IX. PRINCIPAL RECOMMENDATIONS

1. Assuming that NASA and the Department of Energy elect to stimulate highway-related applications of solar electric power, their attentions for the immediate future should center upon the highway departments of the various states:

(a) Little benefit can be expected from working with the manufacturers of highway-related electrical equipment, such as signs, since these manufacturers have little to gain through the introduction of solar power supplies for their equipment, and are in a poor position to influence the states in the selection of power equipment, even if they chose to do so.

(b) The states, on the other hand, have the most to gain from the adoption of solar electric power in circumstances where such a power source is economical. Furthermore, once a state highway department specifies solar electric power when requesting bids for equipment of any kind, the apparatus needed to supply the solar power will take shape with surprising rapidity.

(c) Furthermore, the state highway departments are already accustomed to accepting guidance from many agencies of the Federal Government, and are accustomed to working with federal regulations.

2. In working with the highway departments of the various states, NASA/DOE should abandon the notion of stimulating any particular class of solar applications, such as signs or lighting, in preference to other classes. From the engineering and economic standpoints, all highway applications are very similar, and it should therefore be the immediate objective to encourage the consideration of solar electric power for any appropriate highway application whatsoever.

3. As a starting point, NASA/DOE must strive to educate and familiarize the highway departments of the various states with the nature of solar power and its proper applications. This process can be accelerated in two ways:

(a) Representatives of NASA/DOE can visit the highway departments of the various states personally, where, in practically all cases, they can expect an excellent reception. The purpose of such visits should be to discuss specific potential applications for solar power in the greatest possible detail, so as to give the highway officials a better understanding of the advantages and disadvantages of this technique.

(b) This work can be reinforced by providing the state highway departments with written material which describes the capabilities and specifications of solar power, and shows the states how to specify solar power for applications in which its use appears advantageous. The handbook prepared by TMA in connection with this program may be taken as a first step in this direction.

4. NASA/DOE can also accelerate the acceptance of solar power by exerting influence to permit the use of apparatus, such as strobe lights, which have unusually low power consumption, on projects which are to be funded wholly or in part by the Federal Government.

5. Finally, NASA/DOE can encourage first installations of solar electric power by providing for their partial subsidization. It is recommended that this be done under the following conditions:

(a) That each application and proposed equipment specification be first submitted to NASA or the Department of Energy for approval.

(b) That such subsidies be granted on a declining basis. In other words, the first solar installation in each state might receive 75% federal support, the second 50%, the third 25%, and no support thereafter.

Were such subsidies adopted, TMA estimates roughly that the total granted would not exceed $1.5-million.

6. After making three solar installations, a state highway department should have developed the capability to make sound independent judgments concerning the performance, applicability, and overall costs of a solar electric power installation. Thereafter, the state should be able to identify on its own those applications in which the use of solar electric power would be beneficial. At the same time, relationships should also have been established between the state and the distribution system through which solar equipment can be supplied. Thus there is every reason to expect the market thenceforth will operate in a self-sustaining fashion.

APPENDIX A

TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

Device	Typical Load Components	Assumed Device Operating Duty	Estimated 24-hour Avg. Load	Reliability Requirements
1. Lighting				
a. Area Lighting				
(1) Expressway Interchange (each luminaire)	- 1 high-pressure sodium lamp, 400W, continuous - 1 ballast, 50W continuous - 1 inverter, 95% efficient, continuous	14 hours per day	276W	High
(2) Rural Road Intersection	- 1 high-pressure sodium lamp, 100 W, continuous - 1 ballast, 14W continuous - 1 inverter, 95% efficient, continuous	14 hours per day	70W	High
b. Navigation Light System	- 6 incandescent lamps, 60W each, steady-burning	14 hours per day	210W	Very high
2. Signs				
a. Warning Sign With Beacons	- 2 lamps, 67W each, flashing alternately - 1 solid-state or motorized flasher control, 5W, continuous	Continuous	72W	Very high
b. Fiber Optic Warning Sign	- 1 glass-halogen lamp, 42W, continuous	Continuous	42W	Very high

TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

Device	Typical Load Components	Assumed Device Operating Duty	Estimated 24-hour Avg. Load	Reliability Requirements
Variable-Message Signs				
(1) Lamp Matrix Type (small)	- Control electronics, 5W continuous - 1050 lamps, 20W each, fewer than 30% on at one time	Continuous	6300W	Very high, if message is safety-related
(2) Flipping Disc Type (small)	- Control electronics, 5W continuous - 1050 reflective discs, 0.5 watt-seconds per flip pulse, each message change requires pulsing all discs to reset, then pulsing fewer than 30% to set new message - Lighting, 150W, 14 hours per day	Message changed 4 times per day	93W	Very high, if message is safety-related
(3) Drum Type	- Control electronics, 15W continuous - 1 motor, 200W, 30 seconds each message change - Lighting, 150W, 14 hours per day	Message changed 4 times per day	93W	Very high, if message is safety-related
(4) Flap Type	- 1 motor, 420W, 5 seconds each message change - 1 timer, 3W continuous - 1 flashing beacon, 67W, 50% duty, operates when one of the two possible messages is displayed	Message changed 4 times per day	20W	Very high, if message is safety-related

TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

Device	Typical Load Components	Assumed Device Operating Duty	Estimated 24-hour Avg. Load	Reliability Requirements
d. Overhead Directional Sign Illumination	- 2 fluorescent tubes, 100W each	14 hours per day	117W	High
3. Railroad Crossing Signals				
a. Flashing Lights Only	- Controller, 5W continuous - 8 lamps, 18W each, flashing 50% duty when in operation - 1 bell, 4W when in operation	In operation 10% of the time	13W	Extremely high
b. Lights with Gates	- All of the above - 2 gate motors, 170W each, 20 seconds each operation cycle	2 cycles per hour	16W	Extremely high
4. Radio Installations				
a. VHF, UHF, and Microwave				
(1) VHF or UHF FM Repeaters	- 1 receiver, 5W squelched 95% of the time, 25W unsquelched 5% of the time - 1 transmitter, 100W RF output, 255W input, keyed 5% of the time	Continuous	19W	Very high

TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

Device	Typical Load Components	Assumed Device Operating Duty	Estimated 24-hour Avg. Load	Reliability Requirements
(2) VHF or UHF FM Remote Base Stations With Microwave Link	- 1 FM receiver, 5W squelched 95% of the time, 25W unsquelched 5% of the time - 1 FM transmitter, 100W RF output, 255W input, keyed 5% of the time - 1 microwave transmitter-receiver pair, 40W continuous	Continuous	59W	Very high
(3) Microwave Repeaters	- 2 transmitter-receiver pairs, 40W each pair, continuous	Continuous	80W	Very high
b. CB Radio Repeaters	- 1 base station transceiver, 20W when transmitter keyed, 1W when receiving - 1 tone decoder for remote control, 5W when transmitting, 0.2W when receiving	Transmitting 5% of the time	11W	Very high
c. Travelers' Information Radio Transmitters	- 1 AM radio transmitter with endless loop tape player, 60W continuous	Continuous	60W	High
5. Cathodic Protection for Bridges				
a. On Bridge Decks	- D.C. power supply, 500W-800W continuous	Continuous	500-800W	Moderate
b. On Concrete Footings	- D.C. power supply, 5-10W continuous	Continuous	5-10W	Moderate

TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

Device	Typical Load Components	Assumed Device Operating Duty	Estimated 24-hour Avg. Load	Reliability Requirements
6. Instruments				
a. Traffic Counters (Permanently located)	- Continuous drain, 75mW - Each vehicle count, 0.045mW-HR per vehicle, 60,000 vehicles per day - Recording counts on punched tape, 2mW-HRS per punching cycle, 24 cycles per day	Continuous	0.19W	Moderately high
b. Speed Monitor	- Electronics, 7W continuous - 1 sign with 2 flashing beacons, 67W each, flashing alternately for 20 seconds when triggered	Triggered 20 times per day	7.3W	Moderately high
c. Height Monitor	- 2 LED light sources, plus 2 detectors and control electronics, 45W continuous - Heater, 50W continuous in cold weather - 1 sign with 2 flashing beacons, 67W each, flashing alternately for 20 seconds when triggered	Triggered 10 times per day	95W	Very high
d. Intervehicle Gap Monitor	- Control electronics, 18W continuous - Infrared light source and detector, 36W continuous - Heater, 110W, continuous in cold weather - 1 sign with 800W lighted section, 20 seconds when triggered	Triggered 30 times per day	168W	Moderately high

TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

Device	Typical Load Components	Assumed Device Operating Duty	Estimated 24-hour Avg. Load	Reliability Requirements
e. Fog Detector	- 1 LED light source, plus detector and control electronics, 50W continuous - Heater, 250W continuous in cold weather - Flap-type variable message sign, 0.6W-hour each message change	Triggered 2 times per day	300W	High
f. Ice Detector	- 1 sensor plus processor unit, 100W continuous - 1 signal transmitter, 1 watt RF output, 20W input, continuous	Continuous	120W	High
7. Portable Power Supply	- Solar power system for operating roadside signs or safety equipment to evaluate effectiveness before permanent installation - Product concept suggested to TMA by an interviewee. No such device is currently in use.	Continuous	100W	Very high
8. Motorist Aid Call Box	- Continuous power drain, 0.003W - When activated, 3.75W for 30 seconds, plus 3 bursts of 6.3W for 1 second each	Activated once per day	0.04W	High
9. Other Applications				
a. Traffic Signals				
(1) Stop Lights (Minimum)	- 4 signal heads, 3 lamps each, 60W each, only one on at a time, steady-burning - Controller, 20W continuous	Continuous	260W	Very high

TYPICAL POWER CONSUMPTION OF HIGHWAY-RELATED DEVICES

Device	Typical Load Components	Assumed Device Operating Duty	Estimated 24-hour Avg. Load	Reliability Requirements
(2) Four-Way Flashing Beacons	- 4 lamps, 60W each, flashing alternately in pairs - 1 controller, 5W continuous	Continuous	125W	Very high
b. Portable Barricade Flasher	- 1 lamp, 1.56W, 0.1 second each flash, 65 times per minute	Continuous	0.17W	Very high
c. Roadside Rest Area (Rural)	- Water heater, 5500W, 10% duty - Space heater, 7500W, 50% duty in cold weather - Water and sewage pumps, 10,000W, 10% duty - Area lighting for access ramps, parking area, picnic area, and buildings; 55 luminaires, 20,000W, 14 hours per day.	Continuous	17,000W	High
d. Outdoor Advertising Sign (12'x 25')	- 2 fluorescent lamps, 100W each, 8 hours per day in winter - Ballast, 50W, 8 hours per day in winter - Inverter, 95% efficient, 8 hours per day in winter - Timer, 5W continuous	Continuous	93W	Moderate

Sources: Manufacturers, TMA

APPENDIX B

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

C-2

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

BRIDGE NAVIGATION LIGHTS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. > 2 Miles*	Expect to Install 1978-82	Expected Line Ext. Required > 2 Miles*	Comments
Alabama	50	15	5	5	3	
Alaska	4	1	0	0	0	
Arizona	6	2	0	0	0	
Arkansas	25	5	3	5	2	
California	20	0	0	2	0	
Colorado	0	0	0	0	0	
Connecticut	0	0	0	0	0	**
Delaware	17	0	0	0	0	
Florida	200	20	10	10	5	
Georgia	10	2	0	0	0	
Idaho	2	1	0	1	0	
Illinois	0	0	0	0	0	**
Indiana	0	0	0	0	0	**
Iowa	13	3	0	2	0	
Kansas	0	0	0	0	0	
Kentucky	55	12	3	12	0	
Louisiana	200	30	0	30	0	
Maine	100	5	0	5	0	
Maryland	0	0	0	0	0	**
Massachusetts	24	0	0	0	0	
Michigan	12	1	0	1	0	
Minnesota	12	2	0	0	0	
Mississippi	8	0	0	5	0	
Missouri	20	8	0	3	0	
Montana	0	0	0	0	0	

*Criterion of 2-mile extension due to high power requirements, resulting in high solar system costs

**Under control of Bridge Authority

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

BRIDGE NAVIGATION LIGHTS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. > 2 Miles*	Expect to Install 1978-82	Expected Line Ext. Required > 2 Miles*	Comments
Nebraska	0	0	0	0	0	
Nevada	0	0	0	0	0	
New Hampshire	3	1	0	0	0	
New Jersey	80	2	0	0	0	
New Mexico	0	0	0	0	0	
New York	100	5	0	5	0	
North Carolina	32	0	0	1	0	
North Dakota	0	0	0	0	0	
Ohio	0	0	0	0	0	**
Oklahoma	10	0	0	0	0	
Oregon	0	0	0	0	0	**
Pennsylvania	18	2	0	0	0	
Rhode Island	0	0	0	0	0	**
South Carolina	30	1	0	3	1	
South Dakota	0	0	0	0	0	
Tennessee	20	4	0	4	0	
Texas	250	8	4	10	5	
Utah	0	0	0	0	0	
Vermont	0	0	0	0	0	
Virginia	24	1	0	3	0	
Washington	58	6	0	4	0	
West Virginia	18	0	0	0	0	
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Total	1,421	137	25	111	16	

*Criterion of 2-mile extension due to high power requirements, resulting in high solar system costs

**Under control of bridge authority

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

LIGHTED WARNING SIGNS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	0	0	0	0	0	
Alaska	110	96	0	30	0	
Arizona	0	0	0	0	0	
Arkansas	50	50	0	50	0	
California	750	250	3	250	3	
Colorado	90	0	0	0	0	
Connecticut	12	0	0	0	0	
Delaware	2	0	0	0	0	
Florida	150	100	2	125	2	
Georgia	45	15	0	5	0	
Idaho	67	62	0	5	0	
Illinois	300	60	3	60	3	
Indiana	0	0	0	0	0	
Iowa	20	10	0	2	0	
Kansas	0	0	0	0	0	
Kentucky	35	2	1	2	1	
Louisiana	0	0	0	0	0	
Maine	100	100	0	0	0	
Maryland	200	200	50	0	0	
Massachusetts	100	20	5	30	5	
Michigan	90	20	0	10	0	
Minnesota	24	20	2	18	2	
Mississippi	35	17	2	17	2	
Missouri	6	0	0	0	0	
Montana	0	0	0	0	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

LIGHTED WARNING SIGNS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	80	80	20	125	10	
Nevada	204	50	0	25	0	
New Hampshire	500	20	0	20	0	
New Jersey	200	20	0	65	0	
New Mexico	30	5	2	5	2	
New York	0	0	0	0	0	
North Carolina	130	30	5	45	7	
North Dakota	36	18	12	12	8	
Ohio	0	0	0	0	0	
Oklahoma	15	0	0	0	0	
Oregon	10	3	2	0	0	
Pennsylvania	1	1	0	1	0	
Rhode Island	0	0	0	0	0	
South Carolina	630	60	3	60	3	
South Dakota	50	36	0	50	0	
Tennessee	100	0	0	0	0	
Texas	500	150	0	100	0	
Utah	4	4	4	4	4	
Vermont	0	0	0	0	0	
Virginia	75	20	0	20	0	
Washington	50	50	25	50	25	
West Virginia	23	0	0	0	0	
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Total	4,824	1,575	141	1,186	77	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

VARIABLE MESSAGE SIGNS, EXCLUDING LAMP MATRIX TYPES

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	0	0	0	0	0	
Alaska	0	0	0	0	0	
Arizona	40	0	0*	0	0	Drum
Arkansas	6	0	0	0	0	School zone and drum
California	29	10	0	10	0	Vane and drum
Colorado	9	9	0	0	0	Scroll
Connecticut	0	0	0	0	0	
Delaware	0	0	0	0	0	
Florida	10	10	1	35	3	Fiber optics and disc
Georgia	0	0	0	2	0	
Idaho	3	3	0	3	0	Back-lit incandescent
Illinois	0	0	0	40	0	Drum
Indiana	0	0	0	0	0	
Iowa	0	0	0	0	0	
Kansas	0	0	0	0	0	
Kentucky	0	0	0	0	0	
Louisiana	0	0	0	0	0	
Maine	0	0	0	0	0	
Maryland	2	0	0	0	0	Disc and neon
Massachusetts	0	0	0	6	3	Flap
Michigan	13	13	0	0	0	Flap
Minnesota	0	0	0	24	0	Disc
Mississippi	0	0	0	2	0	
Missouri	0	0	0	0	0	
Montana	0	0	0	0	0	

*Some or all powered by generators

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

VARIABLE MESSAGE SIGNS, EXCLUDING LAMP MATRIX TYPES

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	0	0	0	0	0	
Nevada	2	2	0	0	0	
New Hampshire	0	0	0	0	0	
New Jersey	100	0	0	100	0	Neon and disc
New Mexico	89	89	0	0	0	Flap
New York	10	10	0	0	0	Disc
North Carolina	19	19	2	0	0	
North Dakota	0	0	0	0	0	
Ohio	42	10	1	0	0	Drum
Oklahoma	0	0	0	100	0	Flap
Oregon	0	0	0	0	0	
Pennsylvania	6	6	0	0	0	Drum and disc
Rhode Island	0	0	0	0	0	
South Carolina	1	0	0*	2	0	Drum
South Dakota	0	0	0	0	0	
Tennessee	0	0	0	0	0	
Texas	14	14	0	24	0	Drum, flap, disc
Utah	0	0	0	0	0	
Vermont	0	0	0	0	0	
Virginia	4	4	0	35	0	Presently drums
Washington	4	4	0	11	0	
West Virginia	8	8	0	0	0	Neon
Wisconsin	0	0	0	0	0	
Wyoming	2	2	0	0	0	Disc
Total	413	211	4	394	6	

*Some or all powered by generators

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

RAILROAD CROSSING SIGNALS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	755	150	0	200	10	
Alaska	45	5	0	0	0	
Arizona	270	45	0	180	2	
Arkansas	595	125	0	125	0	
California	4,550	600	0	600	0	
Colorado	500	140	0	300	0	
Connecticut	257	40	0	40	0	
Delaware	129	30	0	40	0	
Florida	1,742	270	0	270	0	
Georgia	960	250	0	300	0	1 solar
Idaho	246	75	12	75	12	
Illinois	4,900	600	0	600	0	
Indiana	3,200	150	0	300	0	
Iowa	1,620	240	0	240	0	
Kansas	1,240	210	0	200	0	
Kentucky	940	260	0	300	0	
Louisiana	865	150	0	150	0	
Maine	450	50	0	50	0	
Maryland	300	5	0	20	0	
Massachusetts	710	150	0	300	0	
Michigan	2,684	400	0	400	0	
Minnesota	1,140	170	0	170	0	
Mississippi	400	125	5	375	5	
Missouri	1,360	160	0	160	1	
Montana	290	40	0	40	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

RAILROAD CROSSING SIGNALS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	800	100	0	100	0	
Nevada	100	40	6	10	2	
New Hampshire	208	32	0	32	0	
New Jersey	1,050	50	0	50	0	
New Mexico	200	50	0	100	0	
New York	2,200	300	0	300	0	
North Carolina	981	40	15	500	20	
North Dakota	300	50	0	50	0	
Ohio	3,200	250	0	250	0	
Oklahoma	890	130	0	250	0	
Oregon	520	75	0	75	0	
Pennsylvania	2,100	250	0	500	0	
Rhode Island	100	100	0	0	0	
South Carolina	500	150	2	300	4	
South Dakota	200	15	0	100	0	
Tennessee	700	175	0	175	0	
Texas	3,500	600	100	600	30	2 solar
Utah	285	20	0	35	0	
Vermont	175	30	0	30	0	
Virginia	917	75	0	75	0	
Washington	750	120	0	120	0	
West Virginia	450	125	0	200	0	
Wisconsin	2,000	300	0	300	0	
Wyoming	132	20	0	20	0	
Total	59,156	7,537	135	9,608	86	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

CATHODIC PROTECTION FOR BRIDGE DECKS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	1	1	0	0	0	
Alaska	1	1	0	0	0	
Arizona	0	0	0	0	0	
Arkansas	0	0	0	0	0	
California	6	6	2	5	5	Have 3 solar; expect 5 solar
Colorado	0	0	0	0	0	
Connecticut	0	0	0	0	0	
Delaware	0	0	0	0	0	
Florida	0	0	0	0	0	
Georgia	0	0	0	1	0	
Idaho	1	1	0	50	0	
Illinois	0	0	0	0	0	
Indiana	0	0	0	0	0	
Iowa	0	0	0	0	0	
Kansas	0	0	0	0	0	
Kentucky	0	0	0	0	0	
Louisiana	0	0	0	0	0	
Maine	0	0	0	0	0	
Maryland	0	0	0	0	0	
Massachusetts	0	0	0	0	0	
Michigan	0	0	0	0	0	
Minnesota	1	1	0	0	0	
Mississippi	0	0	0	0	0	
Missouri	0	0	0	2	0	
Montana	0	0	0	0	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

CATHODIC PROTECTION FOR BRIDGE DECKS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	0	0	0	0	0	
Nevada	0	0	0	0	0	
New Hampshire	2	2	0	0	0	
New Jersey	0	0	0	2	0	
New Mexico	0	0	0	0	0	
New York	0	0	0	0	0	
North Carolina	0	0	0	0	0	
North Dakota	0	0	0	0	0	
Ohio	0	0	0	0	0	
Oklahoma	1	1	0	0	0	
Oregon	0	0	0	0	0	
Pennsylvania	1	1	0	0	0	
Rhode Island	0	0	0	0	0	
South Carolina	0	0	0	0	0	
South Dakota	0	0	0	0	0	
Tennessee	0	0	0	0	0	
Texas	0	0	0	0	0	
Utah	0	0	0	0	0	
Vermont	0	0	0	0	0	
Virginia	0	0	0	0	0	
Washington	0	0	0	0	0	
West Virginia	0	0	0	0	0	
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Total	14	14	2	60	5	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

PERMANENTLY LOCATED TRAFFIC COUNTERS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	85	2	0	0	0	Relocations only
Alaska	17	17	0	10	0	
Arizona	26	7	1	12	2	Presently 1 solar
Arkansas	89	4	0	6	0	Lightning problems
California	150	75	0	35	0	1 solar
Colorado	64	24	0	5	0	
Connecticut	0	0	0	0	0	
Delaware	18	3	0	5	0	
Florida	0	0	0	0	0	
Georgia	61	17	1	14	0	
Idaho	20	5	0	5	0	
Illinois	85	55	0	15	0	
Indiana	0	0	0	0	0	
Iowa	57	25	0	25	0	
Kansas	95	0	0	0	0	Lightning problems
Kentucky	55	0	0	4	0	Lightning problems
Louisiana	57	0	0	0	0	
Maine	30	1	0	5	0	
Maryland	41	4	0	8	0	
Massachusetts	24	5	0	8	3	
Michigan	0	0	0	0	0	
Minnesota	107	53	3	0	0	
Mississippi	70	35	0	35	0	
Missouri	88	0	0	0	0	
Montana	0	0	0	0	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

PERMANENTLY LOCATED TRAFFIC COUNTERS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	0	0	0	0	0	
Nevada	33	0	0	0	0	
New Hampshire	0	0	0	0	0	
New Jersey	30	10	[illegible]	10	0	
New Mexico	43	3	[illegible]	0	0	
New York	0	0	0	0	0	
North Carolina	70	20	0	20	0	
North Dakota	65	0	0	40	0	
Ohio	0	0	0	0	0	
Oklahoma	46	0	0	2	0	
Oregon	0	0	0	0	0	
Pennsylvania	50	5	0	0	0	
Rhode Island	30	0	0	30	0	
South Carolina	30	5	0	5	0	
South Dakota	100	30	0	10	0	
Tennessee	71	20	0	0	0	
Texas	300	30	0	30	0	
Utah	68	11	0	10	5	
Vermont	0	0	0	0	0	
Virginia	16	0	0	0	0	
Washington	80	5	0	45	0	
West Virginia	33	4	0	3	0	
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Totals	2.304	475	5	397	10	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

SPEED MONITORS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	2	2	0	0	0	
Alaska	0	0	0	0	0	
Arizona	0	0	0	0	0	
Arkansas	0	0	0	0	0	
California	0	0	0	0	0	
Colorado	0	0	0	0	0	
Connecticut	0	0	0	0	0	
Delaware	0	0	0	0	0	
Florida	0	0	0	0	0	
Georgia	3	3	0	3	0	
Idaho	0	0	0	1	1	
Illinois	0	0	0	1	0	
Indiana	0	0	0	0	0	
Iowa	2	2	0	1	0	
Kansas	0	0	0	2	0	
Kentucky	0	0	0	0	0	
Louisiana	0	0	0	0	0	
Maine	0	0	0	0	0	
Maryland	0	0	0	0	0	
Massachusetts	1	1	0	0	0	
Michigan	0	0	0	0	0	
Minnesota	0	0	0	2	0	
Mississippi	0	0	0	0	0	
Missouri	0	0	0	0	0	
Montana	0	0	0	0	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

SPEED MONITORS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	0	0	0	1	0	
Nevada	0	0	0	0	0	
New Hampshire	3	3	0	0	0	
New Jersey	1	1	0	0	0	
New Mexico	0	0	0	0	0	
New York	0	0	0	0	0	
North Carolina	10	10	0	0	0	
North Dakota	0	0	0	0	0	
Ohio	0	0	0	0	0	
Oklahoma	0	0	0	0	0	
Oregon	0	0	0	0	0	
Pennsylvania	0	0	0	1	0	
Rhode Island	0	0	0	0	0	
South Carolina	0	0	0	0	0	
South Dakota	0	0	0	1	1	
Tennessee	0	0	0	0	0	
Texas	0	0	0	2	0	
Utah	0	0	0	0	0	
Vermont	0	0	0	0	0	
Virginia	0	0	0	0	0	
Washington	0	0	0	0	0	
West Virginia	0	0	0	0	0	
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Total	22	22	0	15	2	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

HEIGHT MONITORS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	2	2	0	0	0	
Alaska	0	0	0	0	0	
Arizona	1	1	0	0	0	
Arkansas	0	0	0	0	0	
California	45	16	0	16	0	
Colorado	4	2	0	0	0	
Connecticut	0	0	0	0	0	
Delaware	2	0	0	0	0	
Florida	0	0	0	0	0	
Georgia	1	1	0	0	0	
Idaho	3	3	0	30	0	
Illinois	0	0	0	4	1	
Indiana	0	0	0	0	0	
Iowa	0	0	0	0	0	
Kansas	0	0	0	0	0	
Kentucky	0	0	0	0	0	
Louisiana	0	1	0	0	0	Removed
Maine	0	0	0	0	0	
Maryland	0	0	0	0	0	
Massachusetts	6	6	0	0	0	
Michigan	0	0	0	0	0	
Minnesota	0	0	0	2	0	
Mississippi	0	0	0	0	0	
Missouri	0	0	0	0	0	
Montana	0	0	0	0	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

HEIGHT MONITORS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	0	0	0	3	0	
Nevada	0	0	0	0	0	
New Hampshire	0	0	0	0	0	
New Jersey	0	0	0	1	0	
New Mexico	0	0	0	0	0	
New York	0	0	0	0	0	
North Carolina	2	2	0	0	0	
North Dakota	0	0	0	1	0	
Ohio	0	0	0	0	0	
Oklahoma	0	0	0	0	0	
Oregon	0	0	0	0	0	
Pennsylvania	0	0	0	0	0	
Rhode Island	0	0	0	0	0	
South Carolina	0	0	0	1	0	
South Dakota	0	0	0	1	0	
Tennessee	0	0	0	0	0	
Texas	2	2	0	0	0	
Utah	0	0	0	1	0	
Vermont	0	0	0	0	0	
Virginia	4	0	0	0	0	
Washington	3	3	2	6	4	
West Virginia	0	0	0	0	0	
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Total	75	39	2	66	5	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

INTER-VEHICLE GAP MONITORS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect tc Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	0	0	0	6	0	
Alaska	0	0	0	0	0	
Arizona	0	0	0	0	0	
Arkansas	0	0	0	0	0	
California	0	0	0	0	0	
Colorado	0	0	0	0	0	
Connecticut	0	0	0	0	0	
Delaware	1	1	0	0	0	
Florida	0	0	0	0	0	
Georgia	0	0	0	0	0	
Idaho	0	0	0	0	0	
Illinois	0	0	0	1	0	
Indiana	0	0	0	0	0	
Iowa	0	0	0	0	0	
Kansas	0	0	0	0	0	
Kentucky	0	0	0	0	0	
Louisiana	0	0	0	0	0	
Maine	0	0	0	0	0	
Maryland	0	1	0	1	0	One was removed
Massachusetts	0	0	0	0	0	
Michigan	0	0	0	0	0	
Minnesota	0	0	0	0	0	
Mississippi	0	0	0	0	0	
Missouri	0	0	0	0	0	
Montana	0	0	0	0	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

INTER-VEHICLE GAP MONITORS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	0	0	0	0	0	
Nevada	0	0	0	0	0	
New Hampshire	0	0	0	0	0	
New Jersey	1	1	0	1	0	
New Mexico	0	0	0	0	0	
New York	0	0	0	0	0	
North Carolina	1	1	0	0	0	
North Dakota	0	0	0	0	0	
Ohio	0	0	0	0	0	
Oklahoma	0	0	0	0	0	
Oregon	0	0	0	0	0	
Pennsylvania	0	0	0	0	0	
Rhode Island	0	0	0	0	0	
South Carolina	0	0	0	0	0	
South Dakota	0	0	0	0	0	
Tennessee	0	0	0	0	0	
Texas	0	0	0	0	0	
Utah	0	0	0	0	0	
Vermont	0	0	0	0	0	
Virginia	0	0	0	0	0	
Washington	0	0	0	0	0	
West Virginia	0	0	0	0	0	
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Total	3	4	0	9	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

ENVIRONMENTAL INSTRUMENTS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	0	0	0	0	0	
Alaska	0	0	0	5	5	Ice
Arizona	0	0	0	0	0	
Arkansas	2	2	0	0	0	Ice
California	450	450	0	0	0	Ice
Colorado	1	1	0	0	0	Fog
Connecticut	0	0	0	0	0	
Delaware	0	0	0	0	0	
Florida	0	0	0	0	0	
Georgia	0	0	0	0	0	
Idaho	1	1	0	0	0	Ice
Illinois	1	1	0	1	0	Ice
Indiana	0	0	0	0	0	
Iowa	2	2	0	0	0	Ice
Kansas	0	0	0	0	0	
Kentucky	6	0	0	0	0	3 fog, 3 ice
Louisiana	0	0	0	0	0	
Maine	0	0	0	0	0	
Maryland	0	0	0	0	0	
Massachusetts	1	1	0	2	1	Fog
Michigan	3	2	0	2	0	Ice and air quality
Minnesota	0	0	0	0	0	
Mississippi	0	0	0	0	0	
Missouri	0	0	0	0	0	
Montana	0	0	0	0	0	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

ENVIRONMENTAL INSTRUMENTS

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	7	7	1	11	1	Ice
Nevada	3	3	0	0	0	Ice
New Hampshire	0	0	0	0	0	
New Jersey	0	1	0	0	0	Fog; removed
New Mexico	0	0	0	0	0	
New York	0	0	0	0	0	
North Carolina	2	2	1	5	1	Ice
North Dakota	0	0	0	0	0	
Ohio	9	5	0	150	0	Fog
Oklahoma	3	3	0	0	0	Ice
Oregon	0	0	0	0	0	
Pennsylvania	1	1	0	0	0	Fog
Rhode Island	2	2	0	0	0	Fog
South Carolina	0	0	0	0	0	
South Dakota	0	0	0	0	0	
Tennessee	0	0	0	4	1	Fog
Texas	0	0	0	0	0	
Utah	0	0	0	0	0	
Vermont	0	0	0	0	0	
Virginia	0	0	0	0	0	
Washington	2	2	0	0	0	Ice
West Virginia	2	2	0	0	0	Ice
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Total	498	488	2	175	4	

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

MOTORIST AID CALL BOXES

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Alabama	0	0	0	100	0*	
Alaska	0	0	0	0	0	
Arizona	40	0	0*	0	0	Mtd. on dust signs
Arkansas	2	2	0	50	0*	Presently telephone
California	0	0	0	0	0	
Colorado	0	0	0	50	0	
Connecticut	197	197	0	150	150	
Delaware	52	52	0*	52	0	
Florida	564	300	0*	0	0	
Georgia	0	0	0	0	0	
Idaho	0	0	0	0	0	
Illinois	450	150	0*	0	0	Some telephone
Indiana	0	0	0	0	0	
Iowa	0	0	0	0	0	
Kansas	0	0	0	0	0	
Kentucky	50	0	0*	0	0	Telephone
Louisiana	102	102	0	100	0*	
Maine	0	0	0	0	0	
Maryland	50	0	0	0	0	Solar
Massachusetts	100	100	0*	0	0	
Michigan	0	0	0	0	0	
Minnesota	5	5	0*	0	0	
Mississippi	0	0	0	0	0	
Missouri	0	0	0	0	0	
Montana	0	0	0	0	0	

*Some or all powered by generators, line, or user

ESTIMATED OCCURRENCE OF SELECTED POTENTIAL APPLICATIONS

MOTORIST AID CALL BOXES

State	Total Units Now In Place	Units Installed 1973-77	Number Requiring Line Ext. >1/2 Mile	Expect to Install 1978-82	Expected Line Ext. Required >1/2 Mile	Comments
Nebraska	0	0	0	0	0	
Nevada	16	7	0*	0	0	Telephone
New Hampshire	0	0	0	0	0	
New Jersey	60	0	0*	0	0	
New Mexico	0	0	0	0	0	
New York	0	0	0	0	0	
North Carolina	0	0	0	0	0	
North Dakota	0	0	0	0	0	
Ohio	44	22	0	0	0	Battery
Oklahoma	0	0	0	50	0*	
Oregon	6	6	0	0	0	3 solar, 3 battery
Pennsylvania	40	0	0*	0	0	Telephone
Rhode Island	0	0	0	0	0	
South Carolina	0	0	0	0	0	
South Dakota	0	0	0	0	0	
Tennessee	0	0	0	0	0	
Texas	10	10	0	3	0	
Utah	0	0	0	0	0	
Vermont	0	0	0	0	0	
Virginia	0	0	0	0	0	
Washington	0	0	0	0	0	
West Virginia	0	0	0	0	0	
Wisconsin	0	0	0	0	0	
Wyoming	0	0	0	0	0	
Total	1,788	953	0	555	150	

*Some or all powered by generators, line, or user