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Contract DE-FC36-99GO10473
Electrification of Remote Native American Residences

Final report
October 17, 2002

FINAL REPORT SUBMITTED BY NATIVE AMERICAN PHOTOVOLTAICS, INC. (NAPV) FOR ELECTRIFICATION OF REMOTE NATIVE AMERICAN RESIDENCES PROJECT

OBJECTIVES:

To install and maintain photovoltaic (PV) systems for remote residences located in Dilkon and Teesto chapters of the Navajo Reservation. To gain experience with technical, financial, and cultural issues involved with the implementation of an economically sustainable remote PV power program. To familiarize certain sectors of the Navajo Nation with remote PV electrification systems and to help build a base for greater use of remote PV in the future.

ACCOMPLISHMENTS:

- A not-for-profit corporation was established, with a board of directors consisting of Peterson Zah, Greg Smith (Chairman), Roman Bitsuie, Steven Gifis, and Gregory Kiss. An initial base of operations was set up at the Seba Dalkai School in Teesto, and was later moved to a permanent office at the Dilkon School in Dilkon. Having a local presence increased our visibility and assured customers that we are available in the event that they have any questions or problems.

- A staff and crew of Navajos from the Dilkon-Teesto and other areas of the Navajo reservation were hired and trained. Key staff include David Silversmith, Project Manager, and Larry Freddie, crew leader. Training and hardware were supplied by EPV, Inc., TerraSolar USA, Inc., and Trace Engineering (now Xantrex).

- A web site, www.napv.org , was created and has since been updated.

- Under a separate FEMP grant, a 4kW system was installed as an outdoor classroom at the Seba Dalkai School.

- Eighteen PV systems were installed for the following Navajo residents:

Name	System	Address
Elizabeth Dixon	1.2kW June 200l	HC 63, Box 6020, Winslow AZ 86047
Marie Chischillie	1.2kW June 2000	HC 63, Box 256, Winslow AZ 86047
Larry Etsitty	1.2kW July 2000	P.O. Box 1268, Window Rock AZ 86515
Norman Monroe	1.2kW Dec 2000	Box 7120 Winslow AZ 86047
Tommy Barnett	1.2kW Nov 2000	P.O. Box 215 Winslow AZ 86047
Maxine Quahi	1.2kW Feb 2001	12480 N.Leisure Lane, Flagstaff AZ 86004
Christian Morris	1.2kW Feb 2001	P.O.B. 288 Joseph City AZ 86032
Bennie Mann	1.2kW Dec 2000	Box 3095 Indian Wells AZ (Dilkon)
Arthur Yazzie	1.2kW June 2001	HC 63 Box 6082 Winslow AZ 86047
Kee Yazzie	1.2kW June 2000	Box 308 Joseph City AZ 86023
Henry Bonney	1.2kW June 2001	HCR 63 Box 6046 Winslow AZ 86047
Hattie Anderson	1.2kW Nov 2001	c/o T.Barnett Box 215 Winslow AZ 86047
Jerry Freddie	1.2kW July 2001	HC 63 Box 6070 Winslow AZ 86047
Evelyn Jackson	1.2kW June 2001	HC 63 Box 355 Winslow AZ 86047
Henry Billy	1.2kW Nov 2001	HC 63 Box 252 Winslow AZ 86047
Max Chase	1.2kW Dec 2001	P.O.B. 491 Winslow AZ 86047
Cessie Joe	1.2kW May 2002	HC 63 Box 6040 Winslow AZ 86047
Marie Yazzie Navenma	1.2kW Aug 2000	HC 63 Box 412 Winslow AZ 86047

- A site evaluation procedure and customer education/training program was developed and implemented. Appendix A, an NAPV User's Manual, was written as a result of our experiences during the grant period. Information regarding PV's, the system itself, expectations, and a power consumption worksheet are all detailed within this document. Prior to the creation of this document, the necessary information had been communicated orally. But with the creation of this handbook, we are able to review this information with customers during the initial consultation, omitting nothing, and leave the handbook for their reference.

- Other applications for PV power have been discussed with tribal entities, including refrigeration programs for diabetics, PV-integrated housing for sites without utilities, and lighting and water pumping projects.

- NAPV has received two grants from the Navajo Nation Special Diabetes Project and the Navajo Division of Health. With these funds, we will provide PV generated electricity to remote reservation residences. As a result of the successes of the program, the Navajo-Hopi Land Commission has also awarded NAPV a grant for additional PV powered remote residences. None of these successes would have been possible without the initial investment of the Department of Energy.

SUMMARY:

The program has proved technically and operationally successful. Technically, the systems have proved reliable; especially after a systematic user education and training program was implemented. The only significant hardware problem has been the failure of five charge control units, which have been replaced by the manufacturer under warranty.

Customers have been able to use the power for lighting, television, radio, and refrigeration, as predicted.

SYSTEM PERFORMANCE, MAINTENANCE & MONITORING:

With the exception of the charge controllers mentioned above, the hardware has been quite reliable. Initially, some customers overtaxed their systems through excessive usage, but training and communication with the crews have largely solved that problem. The NAPV crews visit systems when they are in the area, typically every other month, and have been able to check battery levels and inverter performance with little extra effort. The systems have been performing generally to specification.

LESSONS LEARNED:

Adequate system size is important. The 1.2 kW system (up slightly in size from the originally proposed 1kW system) is adequate to serve the basic needs of off-grid living, particularly including refrigeration, with reasonably efficient appliances. There appears to be a market for larger systems, approximately 2kW, which we will investigate in the next phase.

The use of a standardized system enabled the crew to develop a systematic approach to installations and also eased the task of training newer crew members.

Communication is extremely important. All local Navajos, the NAPV crew is able to communicate well with all the customers, including those elderly clients who speak little English. By being locally based, travel times to visit clients are much less than they might be on an area as large as the Navajo reservation. With consultations prior to the client's committing to PV installation, through installation, and post-installation support, clients feel involved in the program. Giving the clients a sense of ownership and participation, they are able to ask questions and even point out potential problems. Having a flexible crew, able to discuss scheduling with customers, proved invaluable in creating and maintaining a good rapport with the local community.

The financial performance of NAPV's customers has been good. Payments have generally been on time, sometimes in advance, and have, on only a couple of occasions, fallen three months behind. These situations have been remedied with additional payments. Anecdotal evidence suggests that a significant number of customers in remote areas on the reservation would be able to make payments of up to $150 per month, including a down payment of $2,000, for NAPV's standard system. These payments would be able to support NAPV on an unsubsidized basis. There will remain many lower-income customers who will not be able to make these kinds of payments, and for them some kind of ongoing subsidy program is both necessary and justifiable.

NAPVs operations have taken longer than initially expected, due in part to less than optimal administrative resources, improper cash flow planning, problems with work crew availability, and weather. Inadequate local inventory of the supplies required during installations (certain spacers, bolts and compatible screws) in local hardware stores, as well as suppliers proximity from job sites, caused some delays. With more experience, better planning and communication with local hardware suppliers, this seems to have been remedied. Having onsite administration-secretarial, bookkeeping – which would be viable with a greater volume of business, would solve a number of these issues. Better local office equipment, such as computers, digital camera, and some tools and construction equipment, such as a dedicated work truck with auger, etc., would also improve productivity.

In conclusion, we feel that NAPV's program has been a success. It has met the technical and organizational criteria, and has certainly greatly improved the lives of eighteen families. We seek to secure additional funding, in addition to the new grants from the Navajo-Hopi Land Commission and Navajo Special Diabetes Project, which will enable us to continue operating at a similar scale, if not one of increased productivity, to the past two years. Our on going challenge is to increase the level of installations, become more economically viable and become a greater force for change in Indian lands.

End of report.

NAPV 1200
Solar home system

User's Manual

September 2002

DRAFT

Table of Contents

1. What are Photovoltaics?

Photovoltaics convert light into electricity. Electricity from photovoltaic panels (abbreviated as PV) can be used to power lights and appliances in the home.

PVs use no fuel, produce no emissions, have no moving parts, and make no noise. PV panels require almost no maintenance and can last for many decades. In many ways, they are the best source of energy in the world.

2. About the System

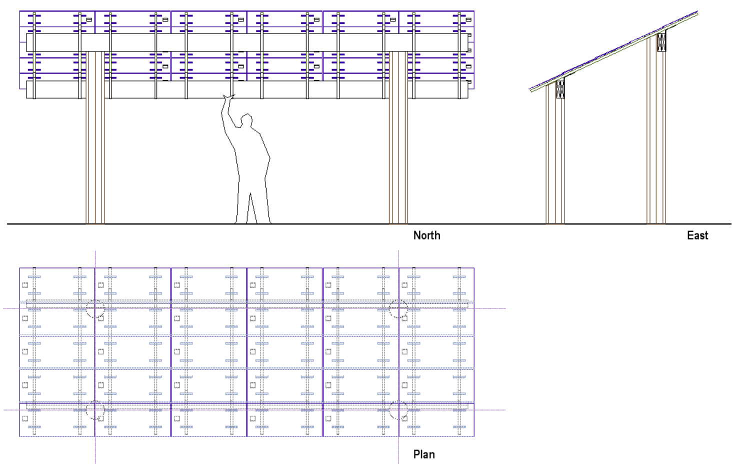


Figure 1

Light falling on photovoltaic panels, or modules, is converted directly to electricity. PV modules are different from solar *thermal* panels, which can look similar but which produce hot water, not electricity. PV modules produce a kind of electricity called Direct Current (DC). This is the same type of electricity that is produced by batteries and is used in many appliances and toys. Electric utilities like NTUA sell Alternating Current (AC) - a different type of electricity - over their wires. To be able to power standard household appliances, our PV system changes the DC from the PV panels and from the batteries into AC by using an *inverter*.

PV modules produce power only when light is shining on them. So that your home has power at night, extra power produced in the day is stored in *batteries*.

Each PV module in your system is rated at about 40 Watts. The 30 modules in the entire system produce a maximum theoretical output of 1200 Watts. In real world conditions the system will produce less power, but on a sunny summer day should produce about 1000 Watts.

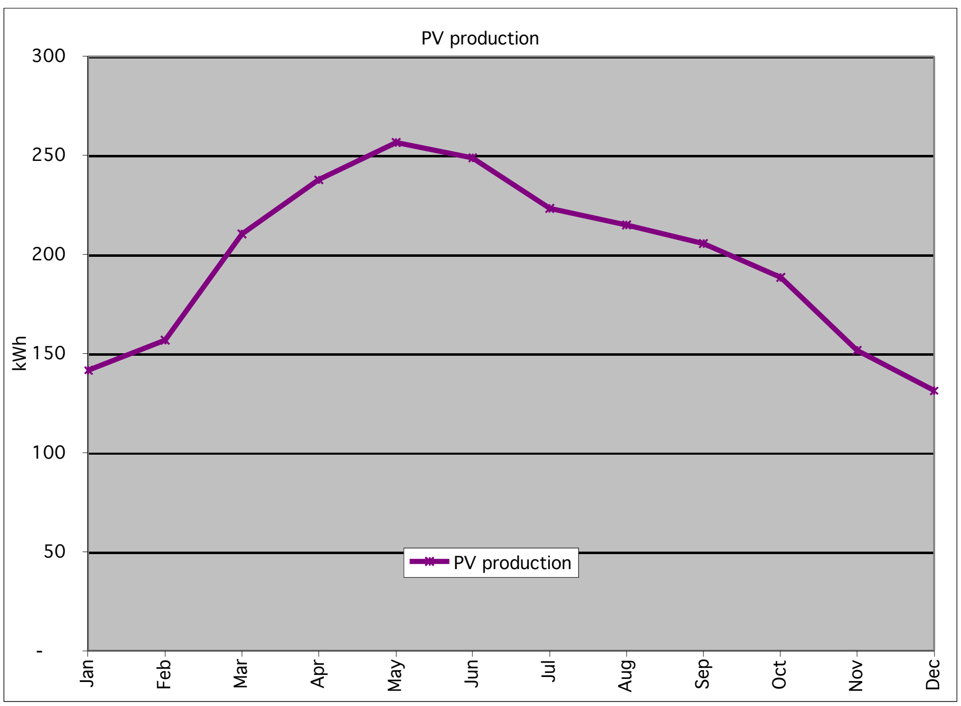
The PV modules are mounted on metal channels which in turn are mounted on a wooden *Ramada* structure. The group of modules are called an *array*; they are all wired together and the DC wires from the modules are connected to the inverter enclosure. In some systems, the inverter may be mounted inside the house. Next to or inside the inverter, which converts DC electricity to AC, is a *Charge Controller*, which regulates the DC power from the PV modules that is used to charge the batteries.

Batteries are always stored outside in a weathertight enclosure. Batteries can emit hydrogen gas and/or acids; both of these are potentially hazardous and better kept outside the house. The batteries are the part of the system that require the most maintenance and have the shortest lifespan. They require that the distilled water in the battery cells be checked and topped up when necessary, and that battery terminals be kept clean. Eventually, after between five and ten years of use, the batteries will need to be replaced.

3. Using the system

3.1. How big is the system?

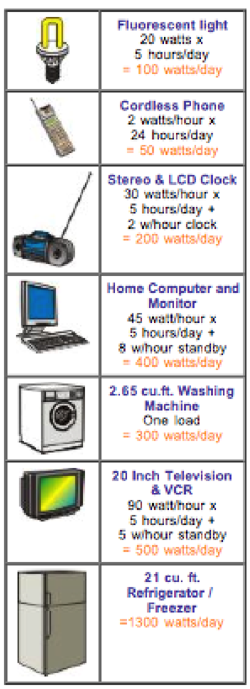
The 1200 Watt system is NAPV's base design. It is powered by 30 PV modules, each of which produces a maximum of 40 watts, for a total of 1200 Watts. We do not make smaller systems because we believe it is important to offer our customers all the important benefits of normal electrical service. These benefits include powering lights, television, radios, small appliances, and refrigeration. In most homes the refrigerator is the largest consumer of electricity, and many PV systems that have been installed on the reservation or in other remote locations are too small to power a refrigerator. Refrigerators are more than a convenience: they make it possible to have a healthy diet, and allow medicines to be stored, etc. Systems significantly smaller than 1200 Watts do not have enough power for standard refrigerators as well as other common needs.



The chart above shows the output of the system over a year. You will notice that the highest output, for the month of May, is about 250 kilowatt-hours. The output for the month of December is less than 150 kilowatt-hours. The output in summer is higher than in winter because days are longer, the sun is higher, and the weather is clearer. This means that you can do more with your system in summer than in winter. Often in winter you will want to use the system more, since days are shorter, and you will turn on the lights earlier and spend more time inside. You should understand and plan for your winter usage, when the system will be most stressed, and the extra usage in the summertime will be a bonus.

For use at night or on very dark days, extra power from the PV modules is stored in batteries. The eight batteries in the standard system are rated to store a maximum of 10,560 watt-hours. This is the equivalent of one to two days production by the PV modules. *In normal operation, the batteries should not be discharged by more than 50%, leaving an effective storage capacity of about 5,000 watt-hours.*

3.2. What can you do with the system?



Your system does not have unlimited power, and the amount it can give you depends on the time of year, on the weather, and on how much you are using it.

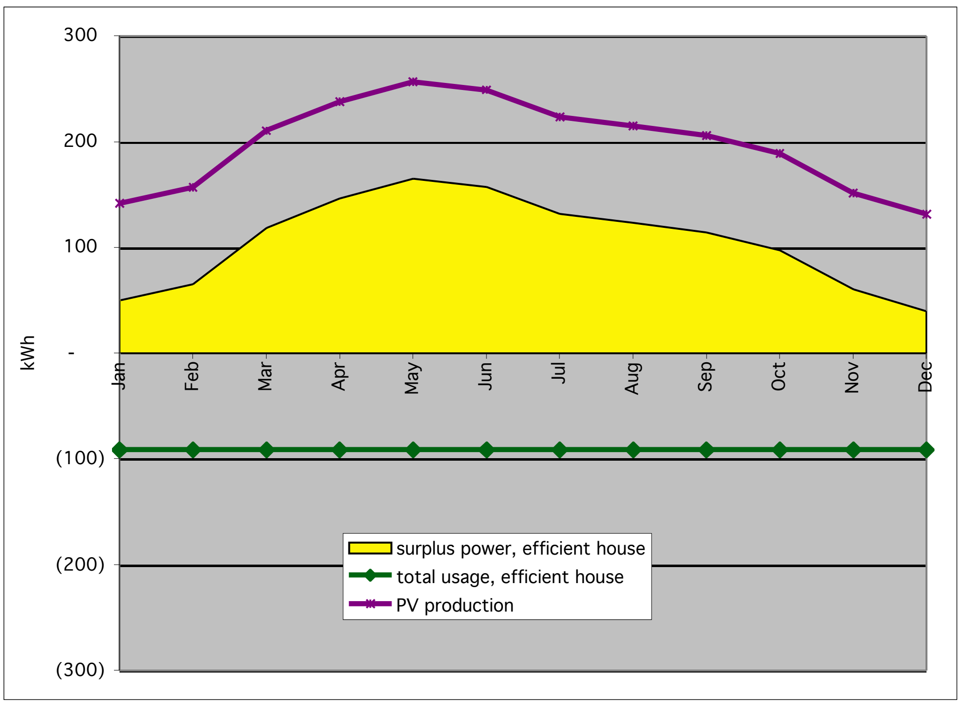
Electric energy is measured in kilowatt-hours. If your system produces one thousand watts (one kilowatt) for one hour, that makes one kilowatt hour. The chart below shows how much a system will produce in a typical year (this is using Winslow, Arizona weather data – performance will vary in other locations).

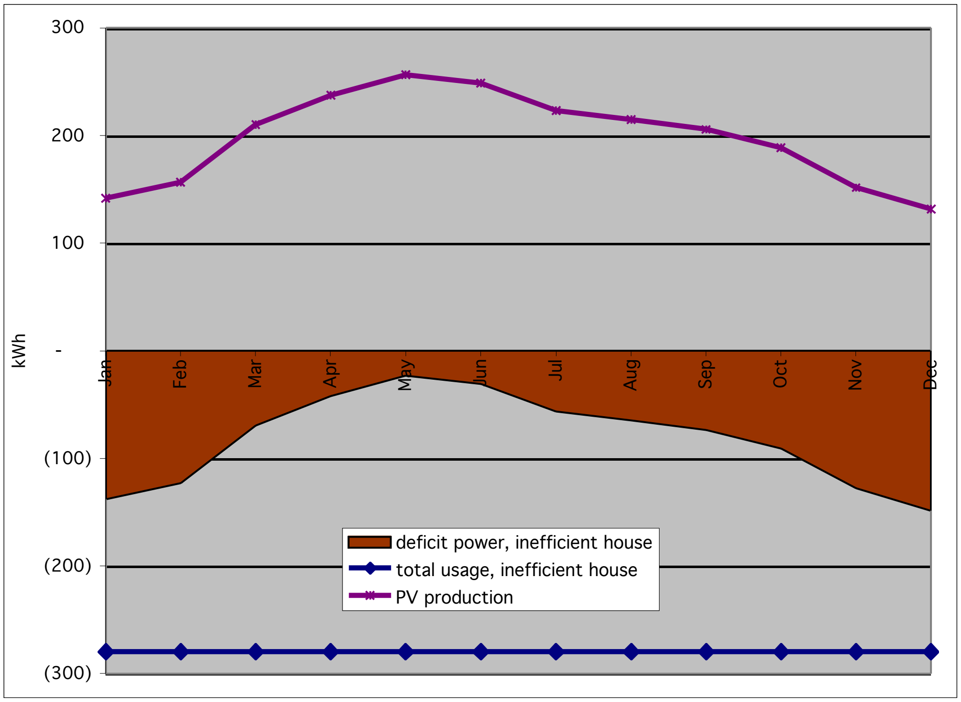
It is very important to understand how much power you use in your home, and to understand how much power your system produces, and what the relationship between these two numbers is.

To illustrate the point, we have made two sets of assumptions about the energy use of a home: one, for a home with energy-efficient appliances, the other with old and inefficient appliances.

Appliances	Efficient	Watts/day	Inefficient	Watts/day
Lights	6 x 15W fluorescents, 6 hours/day	450	6 x 75W incandescents, 6 hours/day	1350
Refrigerator	New efficient model	1640	10 year old model	5590
Color TV	6 hours/day	900	6 hours/day	900
Total		2990		7840
Solar production, winter		5000		5000
Solar production, summer		8300		8300

You can see that the for the efficient home there is power to spare at all times of year, while for the inefficient home there is not enough power in the winter for these loads. The chart below shows the relationship between power generated and power used in an efficient house. The purple line at the top is power generated; the green line at the bottom is power used. The difference is the yellow area – this means that in this house, there is that much extra power available for other appliances.




300
200
100
-
(100)
(200)
(300)
kWh
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
deficit power, inefficient house
total usage, inefficient house
PV production

3.3. Power consumption worksheet.

Below is a worksheet for you to use to figure out how much power you will use in your home. Before agreeing to lease a photovoltaic system, you should complete this form to understand whether you will have enough power for your needs. We strongly recommend that you do not obtain a photovoltaic system unless it fits your needs. You should invest in efficient appliances, such as a new refrigerator, *before* you get your system.

When NAPV's representative visits your home, they will help you complete this evaluation. We encourage you to remember how to fill out the chart, and to update it if you buy new equipment or stop using old equipment. You should always leave some extra power left over during the months when your system produces the least power, like December, or whenever you expect to use the most power.

Appliance	Power, Watts	Hours per day	Total power per day	Remarks
Lighting				
Lights				
Lights				
Lights				
Lights				
Refrigeration				
Refrigerator				
Refrigerator				
Freezer				
TV/Radio/Music				
Television				
Television				
VCR				
VCR				
Satellite				
Radio				
Radio				
Sound system				
Cooking				
Microwave oven				
Toaster				
Crock Pot				
Computer				
Computer				
Printer				
Other				
1				
2				
3				
4				
Total per day				

Appliance	Power, Watts	Hours per day	Total power per day	Remarks
Lighting				
Lights				
Lights				
Lights				
Lights				
Refrigeration				
Refrigerator				
Refrigerator				
Freezer				
TV/Radio/Music				
Television				
Television				
VCR				
VCR				
Satellite				
Radio				
Radio				
Sound system				
Cooking				
Microwave oven				
Toaster				
Crock Pot				
Computer				
Computer				
Printer				
Other				
1				
2				
3				
4				
Total per day				

3.4. System Specifications

System Specifications (PRELIMIANRY)

PV modules	
Type	TerraSolar TS40 or equivalent
Power, STC	40
Quantity	30
System power, STC	1200
Batteries	
Type	Interstate U2200 or equivalent
Capacity, Ah	220
Voltage	6
Quantity	8
Total capacity, Wh	10560
Inverter	Trace DR1524, TS 1500 or equivalent
AC output, W	1500
DC input voltage	24-48

4. Working with NAPV

Summary of terms of lease and maintenance provisions, if applicable.

Maintenance you should do yourself.

When to call NAPV for service.

Contact information.