Appendix A
PV System Sizing Worksheets

I – Determine Your Power Consumption Demands

Use the following worksheet to list the appliances and/or loads that you will run with your PV system. Find out how much power each item consumes while operating. Most appliances have a label on the back that lists the wattage. Specification sheets, local appliance dealers, and product manufacturers are other sources of information. (NOTE: If an appliance is rated in amps, multiply amps by operating voltage (12V, 120V or 240V) to determine watts.) Table A.5 at the end of Appendix A lists power demands for common appliances. Once you have all the wattage ratings, fill out the load sizing worksheet below.

AC and DC Load Sizing Worksheets

1. List all AC loads, wattage, and hours of use per week (Hrs/Wk) in Table A.1. Multiply watts by Hrs/Wk to get watt-hours/wk (Wh/Wk). Add all the watt-hours per week to determine total AC watt-hours per week.

A Note on Phantom Loads- A phantom load is the power consumed by certain appliances even when they are "off." For instance, a stereo or telephone answering machine can consume 5 watts or more continuously, amounting to a substantial load over the course of a day (5 watts x 24 hr = 120 Wh/day). Be sure to account for all phantom loads when calculating AC and DC loads, or plan to eliminate the phantom loads by disconnecting power from these appliances when not in use (through the use of a power strip, for example).

Table A.1 - Calculate AC Loads. If there are no AC Loads, skip to Step 5, Table A.2.

Table A.1 – Calculate AC Loads					
Description of AC Loads Run by Inverter	Watts	X	Hrs/Wk	=	Wh/Wk
Total Watt-Hours per Week AC					

2. Convert AC Watt-Hours/week into DC Watt-hours/week. Multiply Total from Table A.1 by 1.2 to correct for inverter loss._____

3. Enter inverter DC input voltage (usually 12V or 24V)._____

4. Divide Line 2 by Line 3. This is **Total amp-hours per week used by AC loads**._____

Table A.2 – Calculate DC Loads					
Description of DC Loads	Watts	X	Hrs/Wk	=	Wh/Wk
Total Watt-Hours per Week DC					

5. **List all DC loads** in Table A.2 above.

6. DC System Voltage (usually 12V or 24V). Same as Line 3 above. _____

7. **Total amp hours per week used by DC loads**. Divide Total from Table A.2 by Line 6._____

8. Enter Total amp hours per week used by AC loads from Line 4. _____

9. **Total amp hours per week** used by all loads. Add Lines 7 and 8. _____

10. **Average amp hours per day**. Divide Line 9 by 7 days. _____

II – Optimize the Demands on your Power System

At this point it is important to examine your power consumption and reduce your needs as much as possible. First, identify large and/or variable loads (such as water pumps, outdoor lights, electric ranges, AC refrigerators, clothes washers, answering machines, etc.) and try to eliminate them or examine alternatives such as propane, DC, or Energy Star models. The initial cost of DC appliances tends to be higher than AC, but you avoid losing energy in the DC to AC conversion process, and DC appliances are typically more efficient and last longer. Replace incandescent with fluorescent lights wherever possible. Fluorescent lamps provide the same level of illumination while using much less energy. If there is a large load that you cannot eliminate, consider using it only at peak sun hours, or only during the summer (in other words, be creative!). Revise your Load Sizing Worksheets now with your optimized results.

III – Size Your Battery Bank (if necessary)

To choose the proper battery, fill out the Battery Sizing Worksheet below. Other types of storage are available depending on the type of system you are considering (e.g. water storage tanks for pumping applications).

Battery Sizing Worksheet

You need to decide how much storage you would like your battery bank to provide. Often this is expressed as "days of autonomy" because it is based on the number of days you expect your system to provide power without receiving an input charge from the solar array. In addition to the days of autonomy, you should also consider your usage pattern and the critical nature of your application. If you are adding a PV array as a supplement to a generator based system, your battery bank can be slightly undersized since the generator can be operated if needed for recharging. Once you have determined your desired storage capacity, you are ready to consider the following key parameters.

11. Enter your daily amp-hour requirement (from Line 10)._____

12. Enter the maximum number of consecutive cloudy weather days expected in your area, or the number of days of autonomy you would like your system to support._____

13. Multiply the amp-hour requirement by the number of days of autonomy (Line 11 x Line 12). This is the amount of amp-hours your system will need to store._____

14. Enter the depth of discharge for the battery you have chosen. This provides a safety factor to help avoid over-draining the battery bank. (For example, if the discharge limit is 20%, use 0.2.) This number should not exceed 0.8. _____

15. Divide the amp-hours of storage needed (Line 13) by the depth of discharge limit (Line 14). _____

16. Select the multiplier from Table A.3 below that corresponds to the average winter-time ambient temperature your battery bank will experience. _____

17. **Total battery capacity needed**: Multiply the amp-hours (Line 15) by Line 16. This number ensures that your battery bank will have enough capacity to overcome cold weather affects. _____

18. Enter the amp-hour rating for the battery you have chosen_____

19. **Number of batteries wired in parallel**: Divide the total battery capacity (Line 17) by the battery amp-hour rating and round off to the next highest number._____

20. **Number of batteries wired in series**: Divide the nominal system voltage (12V or 24V) by the battery voltage and round off to the next highest number._____

Table A.3: Battery Ambient Temperature Multiplier

°F	°C	Factor
80°F	26.7°C	1.00
70°F	21.2°C	1.04
60°F	15.6°C	1.11
50°F	10.0°C	1.19
40°F	4.4°C	1.30
30°F	-1.1°C	1.40
20°F	-6.7°C	1.59

21. **Total number of batteries required**: Multiply the number of batteries in parallel by the number of batteries in series. _____

IV – Size the PV Array

In Step IV you will calculate the total number of solar modules required for your system. To find the average Sun Hours per day in your area, refer to the tables in Appendix B for the city nearest to your location. If you require year-round autonomy, use the "minimum" figure. If you require 100 percent autonomy in the summer only, use the "maximum" figure.

The peak amperage of the module you will be using can be found in the module specifications. You can also determine peak amperage if you divide the module's wattage by the peak power point voltage (usually 17V to 17.5V).

22. Total average amp-hours per day (from the Load sizing worksheet, Line 10). _____

23. Multiply Line 22 by 1.2 to compensate for efficiency loss from battery charge/ discharge. _____

24. Average Sun Hours in your area (see Appendix B). _____

25. **Total solar array amps required:** Divide Line 23 by Line 24._____

26. Optimum or peak amps of solar modules used. See module specifications._____

27. To determine total number of solar modules *in parallel* required, divide Line 25 by Line 26, then round off to the next highest whole number._____

28. Number of modules needed to provide DC battery voltage (see Table A.4). _____

Table A.4: Number of Modules Needed to Provide DC Battery Voltage

DC Battery Voltage	# of Modules in Each Series String
12	1
24	2
48	4

29. To determine **total number of solar modules required**, multiply Line 27 by Line 28. _____

Worksheet Summary

Load, average amp-hours per day (Line 10) _____
Battery capacity required (Line 17) _____
Capacity and voltage of batteries selected (Line 18) _____
Total number of batteries required (Line 21)_____
Peak amps of solar modules (Line 26) _____
Total number of solar modules required (Line 29) _____

Figure A.5: Energy Use of Some Typical Appliances

DC Appliance	WATTS	AC Appliance	WATTS	AC Appliance	WATTS
CEILING FAN	20	WASHING MACHINE	350 - 500	COMPUTER LAPTOP	20 - 50
TELEVISION (25cm)	45	CLOTHES DRYER (electric)	1800 - 5000	PC	80 - 150
FLUORESCENT LIGHT	5 - 13	GAS	300 - 400	PRINTER	100
STEREO / TAPE PLAYER	40	VACUUM CLEANER	200 - 700	TELEVISION	
REFRIGERATOR		HOT PLATE	1200	25"COLOR	150
16 cf	16	SEWING MACHINE	100	19"COLOR	70
12 cf	10	IRON	1000	12" B&W	20
		COFFEE MAKER	800 - 1200	VCR	40
		MICROWAVE OVEN	550 - 1500	SATELLITE DISH	80
		TOASTER	900 - 1100	STEREO	30
		POWER DRILL	450 - 1000	CLOCK RADIO	1 - 10
		WATER PUMP	250 - 500	CD PLAYER	35
		CEILING FAN	10 - 50	CB RADIO	5
		ELECTRIC BLANKET	200	ELECTRIC CLOCK	3
		BLOW DRYER	1000	FLUORESCENT LIGHT	7 - 26
		SHAVER	15	REFRIG / FREEZER	475 - 725
		DISHWASHER	1200 - 2400	DEHUMIDIFIER	785

Adapted from Creative Energy Technologies (www.cetsolar.com) and the Energy Efficiency and Renewable Energy Clearinghouse (www.eere.energy.gov/consumerinfo/factsheets/ec7.html)

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