

Appendix B

Sample Run of PVONE

This section of the research contains a sample run of the PVONE program used in obtaining the results presented in chapter 7 above. All bold face characters shown at the end of the colon (:) symbols are the input variables. The result shown is for the maximum daily load only. Similar results can be obtained for the average and minimum daily load by entering the appropriate input variable as specified by the program instructions. The total number of modules is also calculated by the program. The user is then asked to enter the number of modules based on the total number of modules. In many instances, this number will rarely be a whole number. Only results obtained by sizing the system based on the maximum load are shown. In block 12, the amount of loan down payment must be based on the total cost of the PV system that will be computed by the program. The output for the total cost must be obtained before proceeding with the rest of the economic analysis. The input variables shown for block 12, is when the system is sized based on maximum daily load only.

**ENTER 1 AT THE CURSOR LOCATION TO READ THE CONTENT
OF THE PROGRAM
TO EXIT THE PROGRAM ENTER 0 AT THE CURSOR LOCATION
ENTER PV BLOCK NEEDED FOR ANALYSIS: 1**

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*****
* PROGRAM CONTENT *
*****
*****
* VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY *
* CENTER FOR ENERGY AND THE GLOBAL ENVIRONMENT *
* INTERACTIVE DESIGN TOOL FOR STAND-ALONE PV SYSTEMS *
*****

PROGRAM NAME: PVONE
PV = 1 :PROGRAM CONTENT
PV = 2 :COMPUTATION OF LOCAL VARIABLES
PV = 3 :INSOLATION ANALYSIS FOR A FLAT COLLECTOR
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PV = 4 :INSOLATION ANALYSIS FOR A TILT COLLECTOR
PV = 5 :RANGE OF INSOLATION LEVELS
PV = 6 :CLASSIFICATION OF DAYS BY INSOLATION LEVELS
PV = 7 :ADJUSTMENT OF CLEAR SKY INSOLATION
PV = 8 :PHOTOVOLTAIC MODULE CHARACTERISTICS
PV = 9 :PHOTOVOLTAIC ARRAY ANALYSIS
PV = 10 :ENERGY OUTPUT ANALYSIS OF PHOTOVOLTAIC SYSTEM
PV = 11 :STORAGE REQUIREMENTS OF PHOTOVOLTAIC SYSTEM
PV = 12 :ECONOMIC ANALYSIS OF PHOTOVOLTAIC SYSTEM
PV = 0 :END OF ANALYSIS

ENTER PV BLOCK NEEDED FOR ANALYSIS: 2

* COMPUTATION OF LOCAL VARIABLES *

NAME OF LOCATION: ' **BLACKSBURG, VIRGINIA** '

NAME OF COUNTRY: ' **UNITED STATES OF AMERICA** '

ENTER THE VALUE OF THE SOLAR CONSTANT IN KW/SQ.METERS: **1.353**

ENTER THE ALTITUDE OF THE LOCATION IN KILOMETERS: **0.600**

ENTER THE LATITUDE OF LOCATION: **37.14**

SELECT THE TYPE OF CLIMATE FOR THE LOCATION

1 = TROPICAL, 2 = MID-LATITUDE SUMMER

3 = SUB-ARCTIC SUMMER, 4 = MID LATITUDE WINTER

ENTER THE TYPE OF CLIMATE FOR THE LOCATION: **2**

ENTER THE LOCAL LONGITUDE FOR THE LOCATION: **80.24**

ENTER LONGITUDE OF STANDARD MERIDIAN FOR THE LOCATION: **75**

ENTER THE STANDARD CLOCK TIME FOR THE LOCATION: **12**

ENTER PV BLOCK NEEDED FOR ANALYSIS: 3

* INSOLATION ESTIMATE FOR A FLAT COLLECTOR*

ENTER THE HEMISPHERE OF THE COUNTRY AND LOCATION:

ENTER 1 FOR NORTHERN HEMISPHERE OR 2 FOR SOUTHERN HEMISPHERE ENTER
THE HEMISPHERE OF THE LOCATION: **1**

ENTER THE MONTH NEEDED FOR DAILY INSOLATION : **4**

ENTER THE DAY OF THE MONTH USING THE JULIAN DAY: **100**

ENTER THE TIME OF DAY TO COMPUTE INSTANTANEOUS INSOLATION: **16**

DO YOU WANT AN OUTPUT FOR THE INSTANTANEOUS
INSOLATION ESTIMATE ?

ENTER **1** FOR YES AND **0** FOR NO

ENTER THE INSTANTANEOUS INSOLATION OUTPUT DECISION: **1**

See Table 7.1 for the output.

ENTER THE TIME TO BEGIN RECORDING INSOLATION: **11**

ENTER THE TIME TO STOP RECORDING INSOLATION: **12.83**

DO YOU WANT AN OUTPUT FOR TOTAL INSOLATION ESTIMATE ?

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE TOTAL INSOLATION OUTPUT DECISION: **1**

See Table 7.2 for the output .

DO YOU WANT AN OUTPUT FOR THE DAILY INSOLATION ESTIMATE ?

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE DAILY OUTPUT DECISION: **1**

See Table 7.3 for the output

DO YOU WANT AN ANNUAL OUTPUT FOR THE DAILY AVAILABLE
INSOLATION AT THE LOCATION ?

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE ANNUAL OUTPUT DECISION: **0**

DO YOU WANT OUTPUT FOR MONTHLY AVAILABLE INSOLATION ?

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE MONTHLY INSOLATION DECISION: **1**

See Table 7.4 for the output.

DO YOU WANT A GRAPHICAL REPRESENTATION OF THE
AVAILABLE INSOLATION ON A FLAT PLATE COLLECTOR ?
SELECT OPTION **1** BELOW IF YOU WILL PROCEED TO DESIGN
THE PV SYSTEM

ENTER **1** FOR INSTANTANEOUS INSOLATION FOR A PARTICULAR DAY

ENTER **2** FOR ANNUAL AVAILABLE INSOLATION

ENTER **0** FOR NO GRAPHICAL OUTPUT OF INSOLATION:

ENTER THE GRAPHICAL OUTPUT DECISION: **1**

Available Power Versus Time of Day
Flat Collector

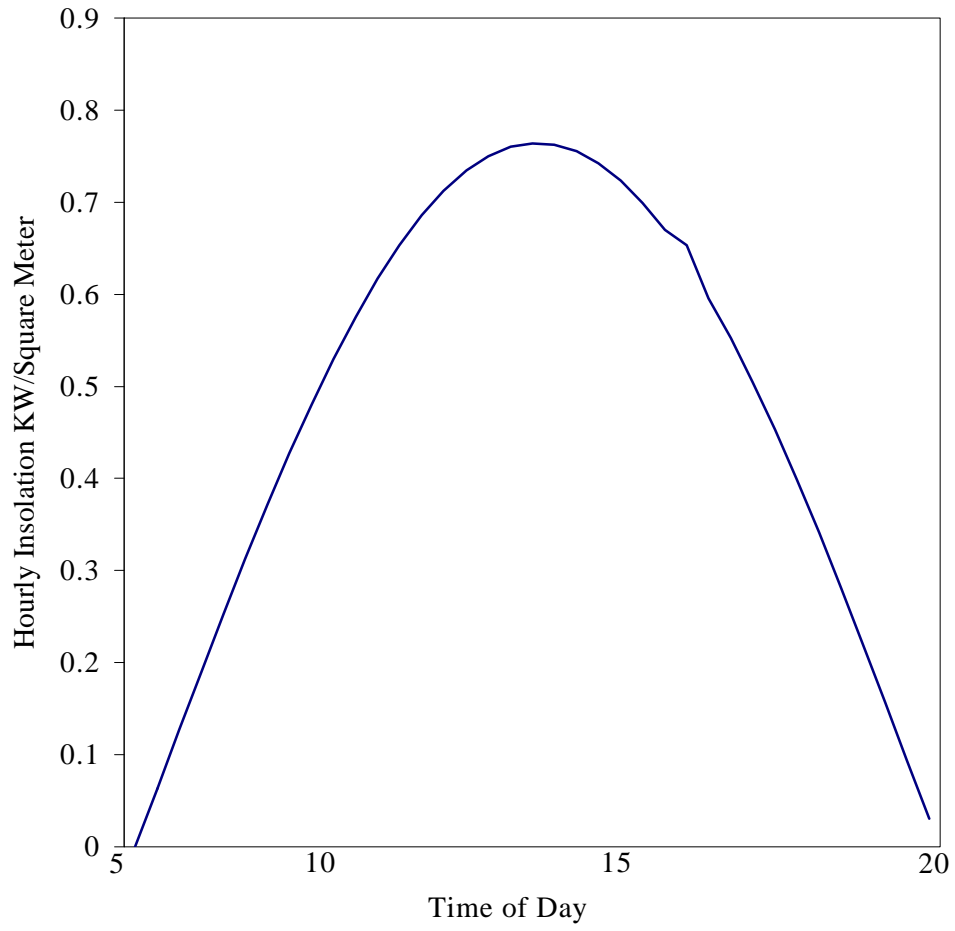


Figure B-1. Daily Insolation For a Flat Plate Collector

ENTER PV BLOCK NEEDED FOR ANALYSIS: 4

* INSOLATION ESTIMATE FOR A TILT COLLECTOR *

ENTER THE HEMISPHERE OF THE COUNTRY AND LOCATION

ENTER 1 FOR NORTHERN HEMISPHERE OR 2 FOR SOUTHERN HEMISPHERE

ENTER THE HEMISPHERE OF THE LOCATION: **1**

ENTER THE MONTH NEEDED FOR DAILY INSOLATION : **4**

ENTER THE DAY OF THE MONTH (DO NOT USE THE JULIAN DAY): **10**

ENTER THE AZIMUTH ANGLE OF THE COLLECTOR: **10.14**

ENTER THE TIME OF DAY TO COMPUTE INSTANTANEOUS INSOLATION: **16**

DO YOU WANT AN OUTPUT FOR THE INSTANTANEOUS INSOLATION ESTIMATE ?

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE HOURLY INSOLATION OUTPUT DECISION: **1**

See Table 7.7 for the output

ENTER THE TIME TO BEGIN RECORDING INSOLATION: **11.00**

ENTER THE TIME TO STOP RECORDING INSOLATION: **12.83**

DO YOU WANT AN OUTPUT FOR INTERVAL INSOLATION ESTIMATE ?

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE INTERVAL INSOLATION OUTPUT DECISION: **1**

DO YOU WANT AN OUTPUT FOR THE DAILY INSOLATION ESTIMATE ?

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE DAILY OUTPUT DECISION: **1**

See Table 7.8 for the output

DO YOU WANT A GRAPHICAL REPRESENTATION OF THE
AVAILABLE INSOLATION ON A TILT PLATE COLLECTOR ?

SELECT OPTION **1** BELOW IF YOU WILL PROCEED TO DESIGN
THE PV SYSTEM

ENTER **1** FOR INSTANTANEOUS INSOLATION FOR A PARTICULAR
TIME OF DAY:

ENTER **0** FOR NO GRAPHICAL OUTPUT OF INSOLATION:

ENTER THE GRAPHICAL OUTPUT DECISION: **1**

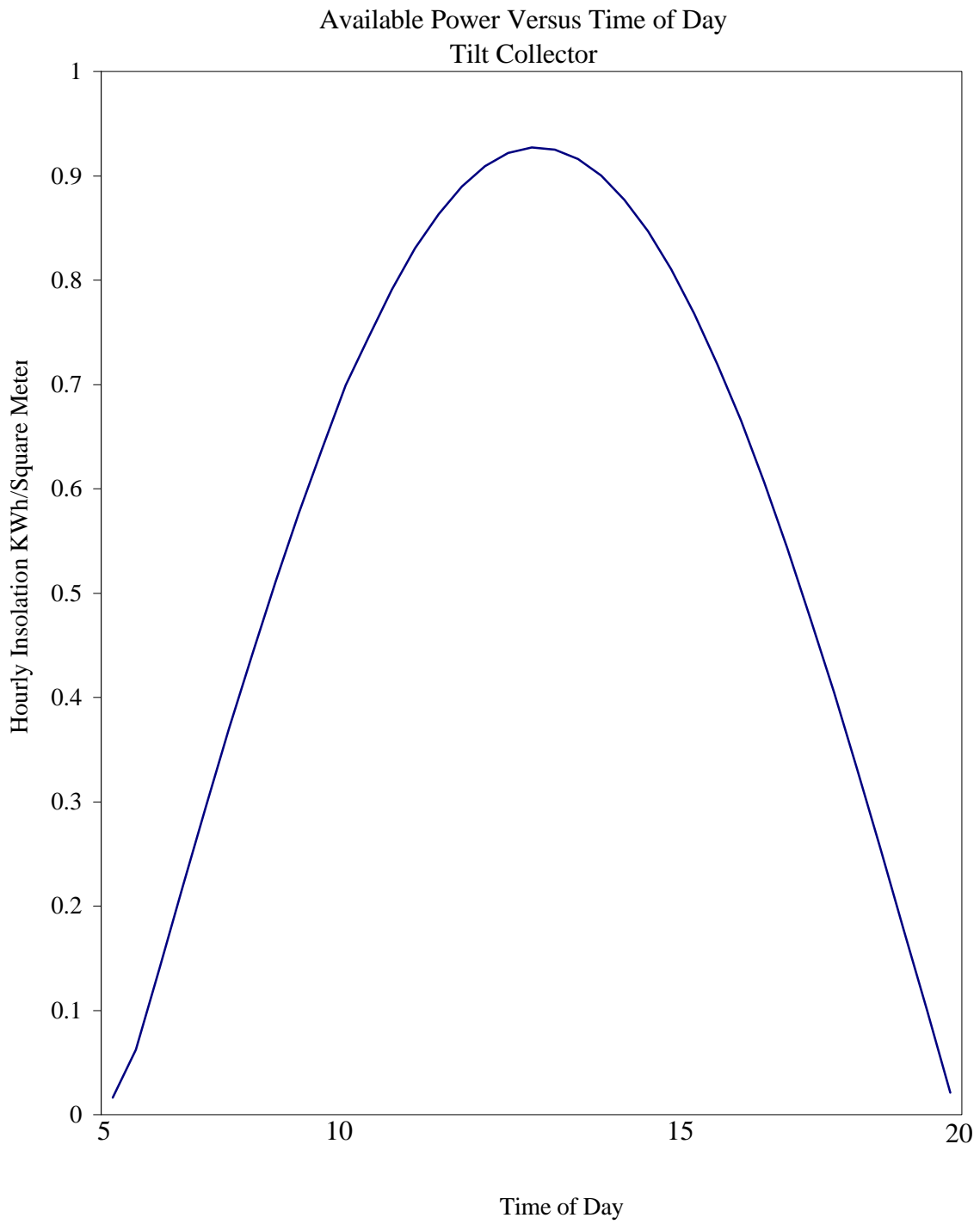


Figure B-2, Daily Insolation For a Tilt Plate Collector

ENTER PV BLOCK NEEDED FOR ANALYSIS: 5

* RANGE OF INSOLATION LEVELS *

ENTER THE MONTH TO ADJUST THE CLEAR SKY MODEL: 4

TYPE OF COLLECTOR USED IN THE ANALYSIS

ENTER FOR 1 FLAT COLLECTOR OR 2 FOR TILT COLLECTOR

ENTER THE TYPE OF COLLECTOR USED IN THE ANALYSIS: 2

DO YOU WANT AN OUTPUT FOR INSOLATION LEVELS

ENTER 1 FOR YES OR 0 FOR NO

ENTER THE OUTPUT DECISION FOR INSOLATION LEVELS: 1

For the output, see Table 7.5 for the flat collector and Table 7.10 for the tilt collector.

ENTER PV BLOCK NEEDED FOR ANALYSIS: 6

* CLASSIFICATION OF DAYS BY INSOLATION LEVELS *

TYPE OF COLLECTOR USED IN THE ANALYSIS

ENTER 1 FOR FLAT COLLECTOR OR FOR 2 TILT COLLECTOR

ENTER THE TYPE OF COLLECTOR USED IN THE ANALYSIS: 2

ENTER THE YEAR TO ADJUST THE CLEAR SKY MODEL: 1990

ENTER THE MONTH WHOSE DAYS ARE TO BE CLASSIFIED: 4

ENTER PV BLOCK NEEDED FOR ANALYSIS: 7

* ADJUSTMENT OF CLEAR SKY INSOLATION *

TYPE OF COLLECTOR USED IN THE ANALYSIS

ENTER 1 FOR FLAT COLLECTOR OR 2 FOR TILT COLLECTOR

ENTER THE TYPE OF COLLECTOR USED IN THE ANALYSIS: 2

ENTER THE MONTH TO ADJUST THE CLEAR SKY MODEL: 4

ENTER 1 TO ADJUST AND COMPARE FLAT COLLECTOR INSOLATION

ENTER 2 TO ADJUST AND COMPARE TILT COLLECTOR INSOLATION

ENTER YOUR CHOICE BASED ON 1 OR 2 ABOVE: 2

DO YOU WANT AN OUTPUT TO ADJUST CLEAR SKY INSOLATION

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE OUTPUT DECISION FOR ADJUSTED INSOLATION: **1**

For the output see Table 7.6 for the flat collector and Table 7.11 for the tilt collector.

ENTER PV BLOCK NEEDED FOR ANALYSIS: 8

* PHOTOVOLTAIC MODULE CHARACTERISTICS *

NAME OF MANUFACTURER: ' **ARCO SOLAR** '

NAME OF MODULE: ' **M 55** '

ENTER THE LENGTH OF PHOTOVOLTAIC MODULE IN METERS: **1.293**

ENTER THE WIDTH OF PHOTOVOLTAIC MODULE IN METERS: **0.330**

ENTER THE RATED POWER OF THE PHOTOVOLTAIC MODULE: **53.0**

ENTER THE MODULE CURRENT AT TYPICAL LOAD: **3.05**

ENTER THE SHORT CIRCUIT CURRENT OF THE MODULE: **3.27**

ENTER THE MODULE VOLTAGE AT TYPICAL LOAD: **17.4**

ENTER THE OPEN CIRCUIT VOLTAGE OF THE MODULE: **21.8**

DO YOU WANT TO PRINT THE MODULE CHARACTERISTICS

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE DECISION TO PRINT MODULE CHARACTERISTICS: **1**

See Table 7.12 for the output of this block of the program

ENTER PV BLOCK NEEDED FOR ANALYSIS: 9

* PHOTOVOLTAIC ARRAY ANALYSIS *

DECIDE ON HOW YOU WANT TO SIZE THE PV SYSTEM BASED

ON DAILY LOAD ENERGY DEMAND

ENTER **1** FOR MAXIMUM DAILY LOAD, **2** FOR AVERAGE DAILY LOAD

OR **3** FOR MINIMUM DAILY LOAD

ENTER THE CHOICE TO SIZE THE PROPOSED PV PLANT: **1**

=====

MAXIMUM ANNUAL DAILY ENERGY DEMAND
160 (KWh)

=====

SELECT THE TYPE OF LOAD FOR PV SYSTEM

ENTER 1 FOR A.C LOADS OR 2 FOR D.C LOADS

ENTER THE TYPE OF LOAD TO BE USED BY PV SYSTEM: 1

ENTER THE EFFICIENCY OF THE POWER CONDITIONING UNIT IN %: 0.95

ENTER THE NUMBER OF POWER CONDITIONING UNITS: 2

IF MODULE EFFICIENCY TAKES INTO ACCOUNT

PACKING FACTOR AND TEMPERATURE CORRECTION FACTOR

ENTER 1 ELSE ENTER THE CORRECT VALUE

ENTER THE PACKING FACTOR OF THE PHOTOVOLTAIC MODULE: 0.99

ENTER THE TEMPERATURE CORRECTION FACTOR TO ADJUST MODULE
EFFICIENCY TO NOCT: 0.99

ENTER THE SOILING FACTOR OF THE PHOTOVOLTAIC MODULE: 1

DETERMINE SOLAR ENERGY AT THE LOCATION FOR ONE DAY

ENTER 1 FOR MAXIMUM, 2 FOR AVERAGE OR 3 FOR MINIMUM

ENTER THE SOLAR ENERGY FOR ONE DAY AT THE LOCATION: 2

TOTAL NUMBER OF MODULES REQUIRED (NM)

NM = 843

MAKE A DECISION WHETHER TO ROUND UP OR TO ROUND DOWN THE NUMBER
OF MODULES

ENTER THE NUMBER OF MODULES: 845

ENTER THE NUMBER OF SUB-ARRAY FIELDS: 5

ENTER THE # OF MODULES IN PARALLEL IN SUB-ARRAY FIELD: 13

ENTER THE # OF MODULES IN SERIES IN SUB-ARRAY FIELD: 13

ENTER THE OPERATING FREQUENCY OF THE ARRAY: 60

DO YOU WANT TO PRINT THE ARRAY CHARACTERISTICS

ENTER 1 FOR YES OR 0 FOR NO

ENTER THE DECISION TO PRINT ARRAY CHARACTERISTICS: 1

For the output, see Table 7.13 for the maximum daily load, Table 7.17 for the average daily load and Table 7.21 for the minimum daily load.

ENTER PV BLOCK NEEDED FOR ANALYSIS: 10

* ENERGY OUTPUT ANALYSIS FOR PHOTOVOLTAIC SYSTEM*

DO YOU WANT THE OUTPUT FOR ENERGY PRODUCED BY THE PV SYSTEM

ENTER **1** FOR YES AND **0** FOR NO

ENTER THE OUTPUT DECISION FOR ENERGY PRODUCED

BY THE PV SYSTEM: **1**

The numerical output is shown in Tables B-1, B-2 and B-3 below.

For the graphical output, see Figure 7.1 for the maximum daily load, Figure 7.3 for the average daily load and Figure 7.5 for the minimum daily load.

SPECIFY THE TYPE OF COLLECTOR USED

ENTER **1** FOR FLAT COLLECTOR OR **2** FOR TILT COLLECTOR

ENTER THE TYPE OF COLLECTOR USED IN THE ANALYSIS: **2**

ENTER THE LAST JULIAN DAY FOR THE PREVIOUS MONTH

(EXCEPT FOR JANUARY): **90**

For the output, see Figure 7.2 for the maximum daily load, Figure 7.4 for the average daily load, and Figure 7.6 for the minimum daily load.

Table B-1, PV Output and Load Demand (Maximum Load)

ENERGY DEMAND AND PV SYSTEM OUTPUT ENERGY		
MONTH	AVERAGE DAILY LOAD ENERGY(KWh/day)	PV SYSTEM ENERGY OUTPUT (KWh/day)
JANUARY	134.635	62.963
FEBRUARY	131.742	95.349
MARCH	128.785	125.861
APRIL	131.025	162.643
MAY	122.275	154.401
JUNE	90.861	216.491
JULY	94.151	213.744
AUGUST	146.409	164.518
SEPTEMBER	120.860	128.156
OCTOBER	121.807	101.490
NOVEMBER	117.536	93.054
DECEMBER	159.944	51.489

Table B-2, PV Output and Load Demand (Average Load)

ENERGY DEMAND AND PV SYSTEM OUTPUT ENERGY		
MONTH	AVERAGE DAILY LOAD ENERGY(KWh/day)	PV SYSTEM ENERGY OUTPUT (KWh/day)
JANUARY	134.635	49.178
FEBRUARY	131.742	74.474
MARCH	128.785	98.306
APRIL	131.025	127.035
MAY	122.275	120.597
JUNE	90.861	169.094
JULY	94.151	166.948
AUGUST	146.409	128.499
SEPTEMBER	120.860	100.098
OCTOBER	121.807	79.271
NOVEMBER	117.536	72.682
DECEMBER	159.944	40.216

Table B-3, PV Output and Load Demand (Minimum Load)

ENERGY DEMAND AND PV SYSTEM OUTPUT ENERGY		
MONTH	AVERAGE DAILY LOAD ENERGY(KWh/day)	PV SYSTEM ENERGY OUTPUT (KWh/day)
JANUARY	134.635	35.766
FEBRUARY	131.742	54.163
MARCH	128.785	71.495
APRIL	131.025	92.389
MAY	122.275	87.707
JUNE	90.861	122.977
JULY	94.151	121.417
AUGUST	146.409	93.454
SEPTEMBER	120.860	72.799
OCTOBER	121.807	57.651
NOVEMBER	117.536	52.859
DECEMBER	159.944	29.248

ENTER PV BLOCK NEEDED FOR ANALYSIS: 11

* STORAGE REQUIREMENTS FOR PHOTOVOLTAIC SYSTEM *

ENTER THE COLDEST 24-HOUR TEMPERATURE OF LOCATION IN DEGREES CELCIUS: **-15**

ENTER THE CAPACITY CORRECTION FACTOR OF THE BATTERY: **0.8**

ENTER THE MAXIMUM DEPTH OF DISCHARGE OF THE BATTERY: **0.6**

ENTER THE DESIRED SYSTEM AVAILABILITY OF THE PV SYSTEM IN %: **0.95**

ENTER THE INDIVIDUAL BATTERY CAPACITY: **180**

ENTER THE NOMINAL BATTERY VOLTAGE: **6.0**

DO YOU WANT AN OUTPUT FOR THE STORAGE REQUIREMENTS

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE OUTPUT DECISION FOR STORAGE REQUIREMENTS: **1**

For the output, see Table 7.14 for the maximum daily load, Table 7.18 for the average daily load, and Table 7.22 for the minimum load.

ENTER PV BLOCK NEEDED FOR ANALYSIS: 12

* ECONOMIC ANALYSIS OF PHOTOVOLTAIC SYSTEM *

ENTER THE EXPECTED USEFUL LIFETIME OF THE PV SYSTEM: **25**

ENTER THE COST PER MODULE: **300**

ENTER THE SUPPORT STRUCTURE COST FOR PHOTOVOLTAIC ARRAY: **19000**

ENTER THE COST PER POWER CONDITIONER: **47400**

ENTER THE COST PER BATTERY: **190**

ENTER THE WIRING AND MATERIALS COST OF THE PV SYSTEM: **12675**

ENTER THE DESIGN, INSTALLATION AND LABOR COST: **50700**

ENTER THE LAND AREA COST: **38025**

ENTER THE COST OF THE CONTROL ROOM: **25350**

ENTER THE ANNUAL INSURANCE PREMIUM FOR PV SYSTEM: **6000**

ENTER THE ANNUAL MAINTENANCE COST OF THE PV SYSTEM: **6000**

ENTER AVERAGE ANNUAL PRICE ESCALATION RATE OVER LIFETIME OF PV SYSTEM IN %: **0.20**

ENTER AVERAGE ANNUAL DISCOUNT RATE FOR BORROWING MONEY OVER LIFETIME OF PV SYSTEM IN %: **0.12**

DETERMINE THE UNIFORM PRESENT WORTH OF COSTS BASED ON

1. EXPECTED LIFETIME OF PV SYSTEM
2. AVERAGE ANNUAL PRICE ESCALATION RATE OVER LIFETIME OF PV SYSTEM
3. DISCOUNT RATE FOR BORROWING MONEY OVER LIFETIME OF PV SYSTEM

ENTER THE UNIFORM PRESENT WORTH OF COSTS BASED ON 1,2,3 ABOVE: **69.17**

ENTER PERCENTAGE OF PV COSTS DEDUCTED FOR TAX OR DEPRECIATION CREDIT IN %: **0.33**

ENTER THE SALVAGE VALUE AFTER PV SYSTEM LIFETIME: **65000**

DO YOU WANT AN OUTPUT FOR TOTAL COST OF THE PV SYSTEM

ENTER **1** FOR YES OR **0** FOR NO

ENTER YOUR OUTPUT DECISION FOR TOTAL PV SYSTEM COST: **1**

For the output, see Table 7.15 for the maximum daily load, Table 7.19 for the average daily load, and Table 7.23 for the minimum daily load.

ENTER THE AMOUNT OF LOAN DOWN PAYMENT: **325922.01**

ENTER THE NUMBER OF YEARS REQUIRED TO PAYOFF THE LOAN: **15**

ENTER THE LOAN DISCOUNT RATE IN %: **0.12**

ENTER THE ANNUAL AVERAGE PRICE ESCALATION RATE OVER TERM OF LOAN IN %: **0.20**

DETERMINE THE LOAN UNIFORM PRESENT WORTH BASED ON

4. YEARS REQUIRED TO PAYOFF LOAN
5. LOAN DISCOUNT RATE
6. ANNUAL AVERAGE PRICE ESCALATION RATE OVER LOAN YEARS

ENTER THE LOAN UNIFORM PRESENT WORTH BASED ON 4,5,6 ABOVE: **27.22**

ENTER PRESENT AVAILABLE ELECTRICITY COST: **0.10**

ENTER THE ANNUAL AVERAGE PRICE ESCALATION RATE OF
ELECTRICITY IN %: **0.20**

ENTER THE DISCOUNT RATE FOR ALTERNATIVE INVESTMENTS IN %: **0.10**

DETERMINE THE BENEFIT UNIFORM PRESENT WORTH BASED ON

1. EXPECTED LIFETIME OF PV SYSTEM

7. ANNUAL AVERAGE PRICE ESCALATION RATE OF ELECTRICITY

8. DISCOUNT RATE FOR ALTERNATIVE INVESTMENTS

ENTER THE BENEFIT UNIFORM PRESENT WORTH BASED ON **1,7,8**

ABOVE: **93.66**

DO YOU WANT AN OUTPUT FOR THE PRESENT VALUE OF THE PV SYSTEM

ENTER **1** FOR YES OR **0** FOR NO

ENTER THE OUTPUT DECISION FOR PV SYSTEM PRESENT VALUE: **1**

For the output, see Table 7.16 for the maximum daily load, Table 7.20 for the
average daily load, and Table 7.24 for the minimum daily load.

ENTER PV BLOCK NEEDED FOR ANALYSIS: 0