

PANDIT DEENDAYAL ENERGY UNIVERSITY

Raisan, Gandhinagar – 382 426, Gujarat, India

B. TECH- Mechanical

Laboratory Manual

Name- Kush Patel

Roll no.- 20BME081

Subject- Industry 4.0 Laboratory

Semester- 5



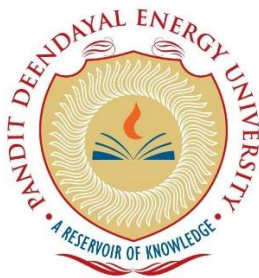
Submitted to

Department of Chemical Engineering

School of Energy Technology, Pandit Deendayal Energy University

PANDIT DEENDAYAL ENERGY UNIVERSITY

Raisan, Gandhinagar – 380 007, Gujarat, India



Chemical Engineering Department

Certificate

This is to certify that

Mr./Ms. Kush Patel Roll no. 20BME081

Exam No. Lab Submission 4 of 3rd Year B. TECH Degree in

Industry 4.0 has satisfactorily completed his/her
term work in Industry 4.0 Laboratory subject during the semester from to at
School of Technology, PDEU.

Date of Submission:

Signature:

Faculty In-charge

Head of Department

Index

Name: Kush Patel

Roll No: 20BME081

Sr. No.	Experiment Title	Pages		Date of Completion	Marks	Sign.
		From	To			
1	3-D Printing					
2	Motion sensor using Arduino uno					
3	Drone simulation using MATLAB/SIMULINK					
4	Computation using python programming					
5	Introduction to MATLAB programming and SIMULINK					
6	Design of smart meter for recording the electricity consumption					
7	Design of ultrasonic proximity sensor with Arduino sensor					
8	Introduction to MATLAB programming and SIMULINK					
9	Design and analysis of solar water heating system using SAM software					

Experiment No.: 1

Title:

Design and analysis of solar water heating system using System Advisor Model (SAM) software.

Aim:

Design a SWH system and assess the annual energy saved for a varying water demand of 50 l/day to 300 l/day (interval of 50 l) for a single collector costing Rs. 160000 (2000\$) for location as discussed during the session. Calculate the LCOE and Capacity factor for varying water demand and plot the results (w.r.t. varying water demand). Working fluid is water.

Software Details:

System Advisory Model (SAM) is a free software that enables detailed performance and financial analysis for renewable energy systems.

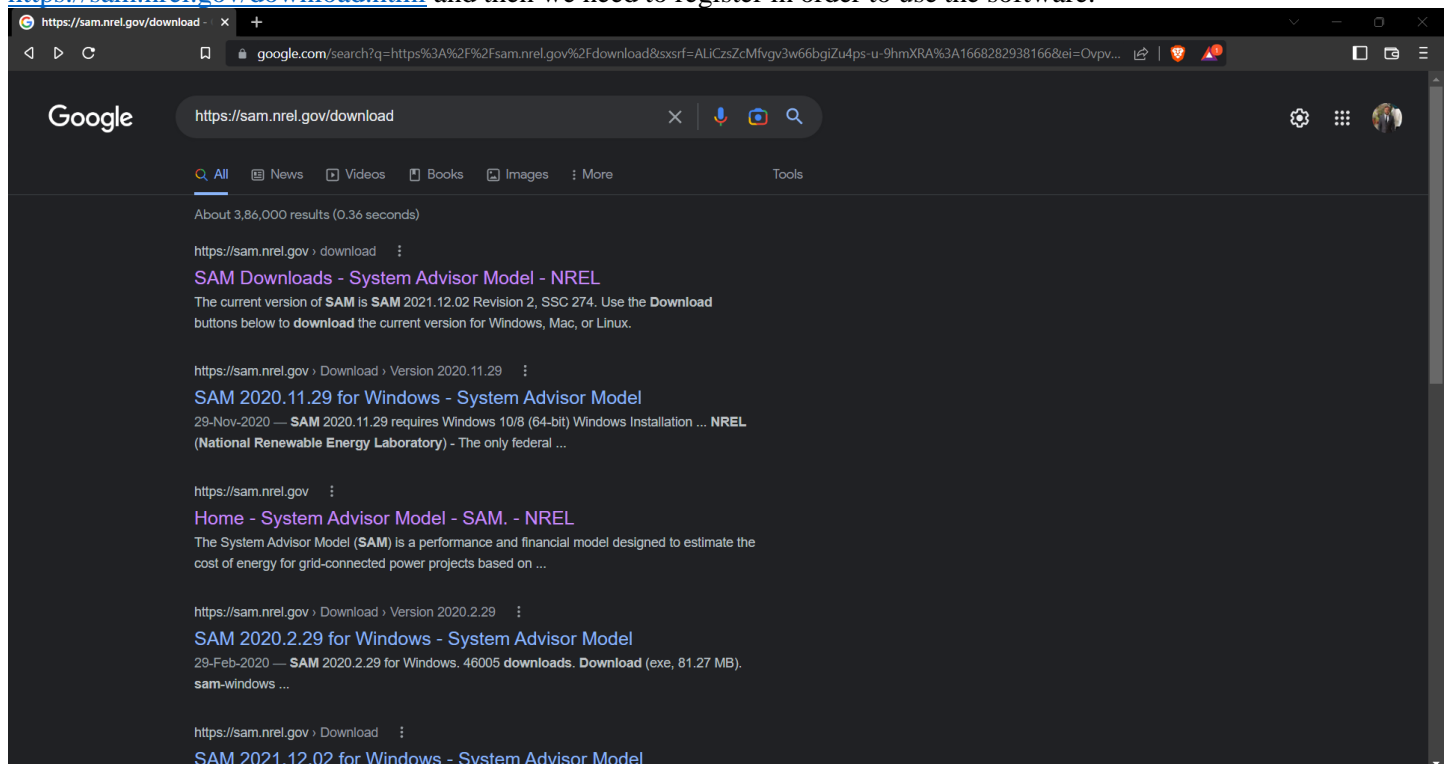
It is a software used by Lawmakers, Utilities, Developers, Engineers, Researchers and Students to study and analyze renewable energy sources.

Some important features of SAM are -

- It provides detailed, time-based financial modeling across multiple market sectors, including complex utility rates, combined with detailed performance modeling.
- It is the only publicly available tool with detailed battery model that accounts for voltage characteristics, calendar and cycle degradation, etc.
- It has built-in parametric, stochastic, probability of exceedance and scripting features enable complex questions to be answered quickly and easily.

In order to install SAM software, we have to download and install the software from

<https://sam.nrel.gov/download.html> and then we need to register in order to use the software.



NREL System Advisor Model (SAM)

Download

SAM Versions

- Version 2020.11.29
- Version 2020.2.29
- Version 2018.11.11
- Version 2017.9.5
- Version 2017.1.17
- Version 2016.3.14
- Version 2015.6.30
- Version 2015.1.30
- Version 2014.11.24
- Version 2014.1.14
- Version 2013.1.15
- Version 2012.11.30
- Version 2012.5.11
- Version 2011.12.2
- Version 2011.6.30
- Version 2010.11.9
- Version 2010.4.12

SAM Downloads

The current version of SAM is SAM 2021.12.02 Revision 2, SSC 274. Use the Download buttons below to download the current version for Windows, Mac, or Linux.

When you first run SAM, you will need to [register SAM](#): Type your email address and, if you are new to SAM, click **Register** to receive a free software key, or paste your existing key and click **Confirm** to confirm your existing key. (If you lost your key, either copy it from the Registration page of an older version of SAM, or click **Confirm** without typing a key to have it automatically emailed to you.)

If you have an older version of SAM on your computer, when you install the new version, it will install side-by-side with older versions(s). Different versions of SAM are independent of each other, so you can install and run different versions simultaneously for comparisons. You can remove (uninstall) older versions of SAM when you are finished using them.

If you need to download an older version of SAM, use the list on the left to find the version you need.

[Release Notes](#)
[Help System as PDF](#)
[Help System as Website](#)
[Introductory Video](#)

Version of SAM, or click **Confirm** without typing a key to have it automatically emailed to you.)

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[Introductory Video](#)

SAM's data viewer displays hourly and subhourly time series data in graphs and tables and is [available for download](#) as a standalone desktop application for Windows.

SAM 2021.12.02 for Windows

• 39781 downloads

SAM 2021.12.02 requires Windows 10/8 (64-bit). We have not yet tested it with Windows 11. It should work, but please [let us know](#) if you have any trouble.

[Download \(exe, 73.53 MB\)](#)

sam-windows-2021-12-02-r2.exe

Windows Installation Instructions

- Double click the `.exe` installation file and follow the instructions in the installation wizard. By default SAM will install in the `c:\SAM\2021.12.2` folder.

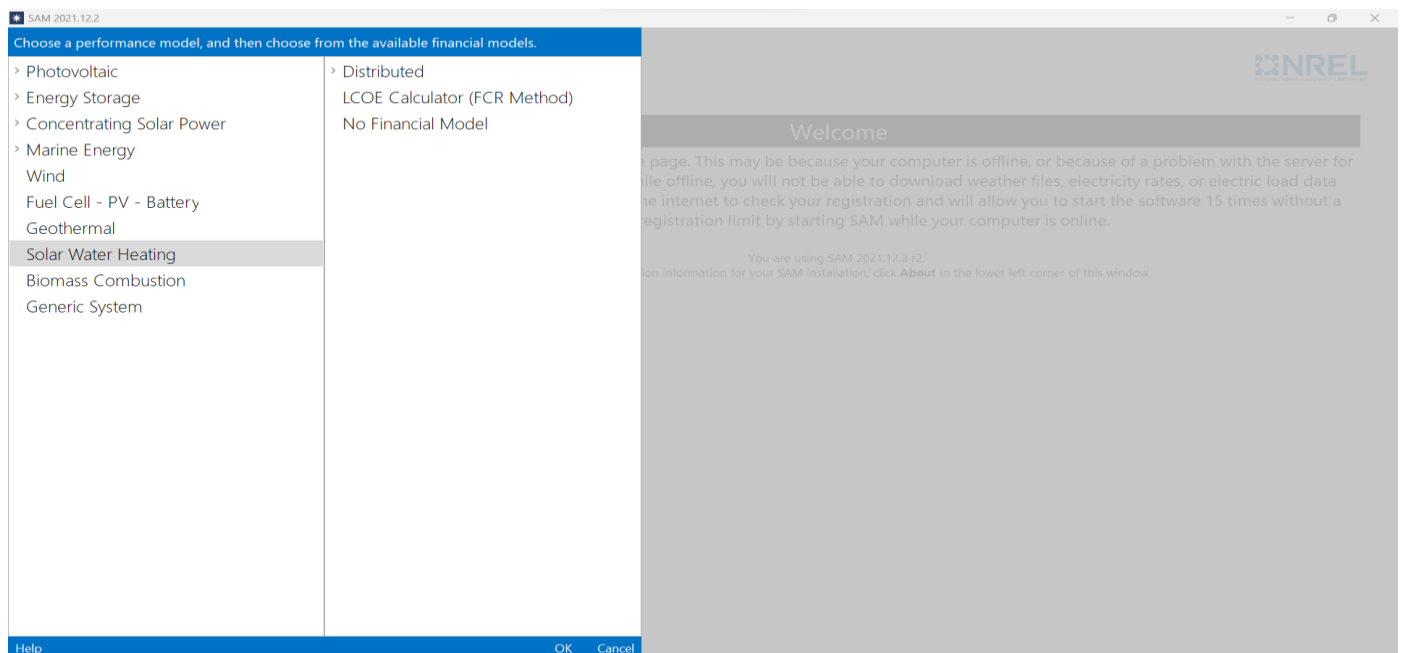
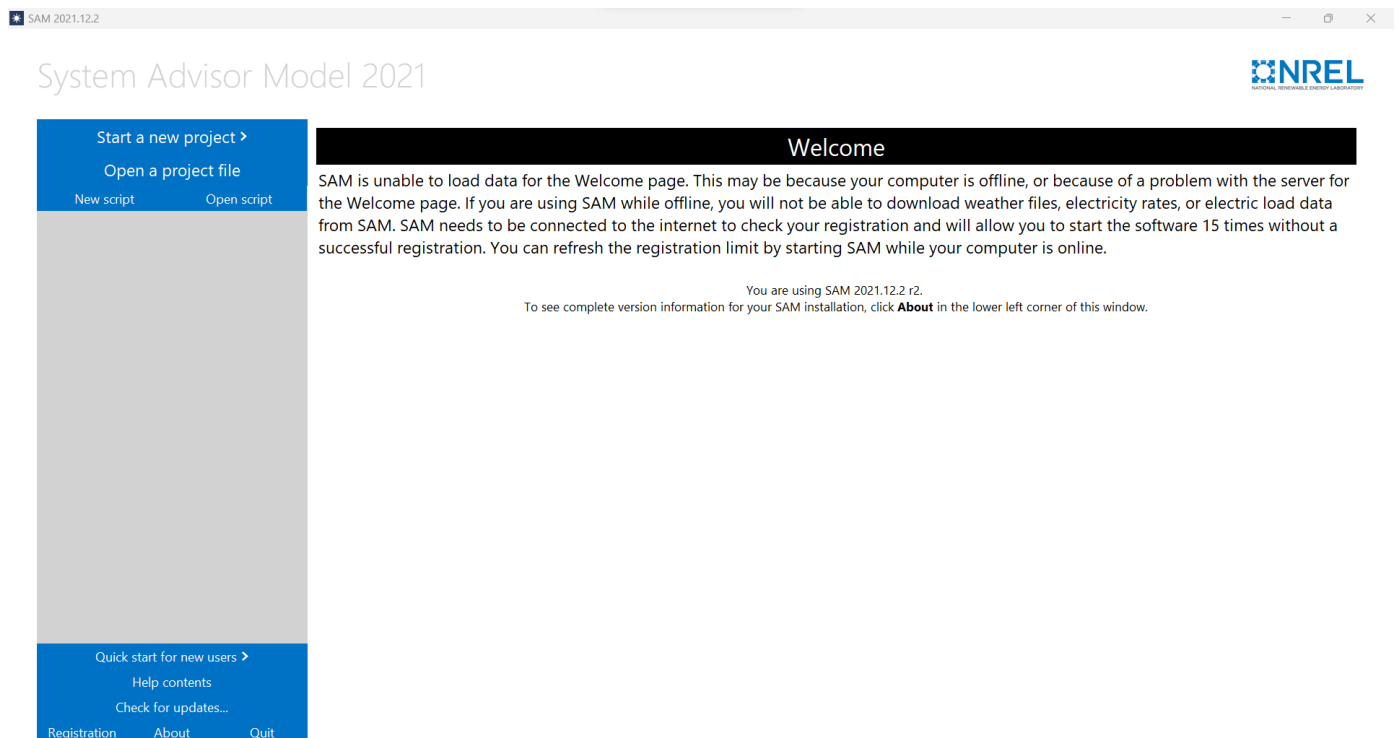
Installation troubleshooting:

If you see a **VCRuntime140_1.dll missing** message after starting SAM, run the `VC_redist.x64.exe` program that comes with your SAM installation. You can find it in the following folder:

`C:\SAM\2021.12.02\runtime\bin`

Procedure:

1. Open the software and create new project. Select Solar Water heating system and LCOE calculator.



2. **Select location – phoenix**
Longitude- -111.98
Latitude- 33.45

SAM 2021.12.2

File Add untitled Help

Solar water, LCOE Calculator

Location and Resource

Solar Water Heating

Financial Parameters

Simulate >

Parameters Stochastic P50 / P90 Macros

Filter: p Name

Name	Latitude	Longitude	Time zone	Elevation	Station ID	Source
daggett_ca_34.865371_-116.783023_psmv3_60_tmy	34.85	-116.78	-8	561	91486	NSRDB
des_moinnes_ia_41.586835_-93.624959_psmv3_60_tmy	41.57	-93.62	-6	263	757516	NSRDB
imperial_ca_32.835205_-115.572398_psmv3_60_tmy	32.85	-115.58	-8	-20	72911	NSRDB
phoenix_az_33.450495_-111.983688_psmv3_60_tmy	33.45	-111.98	-7	358	78208	NSRDB
tucson_az_32.116521_-110.933042_psmv3_60_tmy	32.13	-110.94	-7	773	67345	NSRDB

SAM scans the following folders on your computer for valid weather files and adds them to your Solar Resource library. To use weather files stored on your computer, click Add/remove Weather File Folders and add folders containing valid weather files.

Add/remove weather file folders... Refresh library

Download Weather Files

The NSRDB is a database of thousands of weather files that you can download and add to your solar resource library. Download a default typical-year (TMY) file for most long-term cash flow analyses, or choose files to download for single-year or P50/P90 analyses. See Help for details.

☒ One location ☐ Multiple locations ☐ Advanced download

Type a location name, street address, or lat/lon in decimal degrees Default TMY file Download and add to library...

[For locations not covered by the NSRDB, click here to go to the SAM website Weather Page for links to other data sources.](#)

Weather Data Information

The following information describes the data in the highlighted weather file from the Solar Resource library above. This is the file SAM will use when you click Simulate.

Weather file C:\SAM\2021.12.02\solar_resource\phoenix_az_33.450495_-111.983688_psmv3_60_tmy.csv View data...

Header Data from Weather File

Latitude 33.45 DD Location 78208
Longitude -111.98 DD Data Source NSRDB
Time zone GMT -7
Elevation 358 m
Time step 60 minutes

For NSRDB data, the latitude and longitude shown here from the weather file header are the coordinates of the NSRDB grid cell and may be different from the values in the file name, which are the coordinates of the requested location.

Annual Averages Calculated from Weather File Data

Global horizontal 5.79 kWh/m²/day

Optional Data

3. Now select Solar Water Heating. Set Working fluid and test fluid as water and no of collectors as 1. Set the average daily hot water usage as 50kg/Day.

SAM 2021.12.2

File Add untitled Help

Solar water, LCOE Calculator

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Simulate >

Parameters Stochastic P50 / P90 Macros

Hot Water Draw

Hourly hot water draw profile Edit array... kg/hr Scale draw profile to average daily usage ☒

Total annual hot water draw 18250 kg/year Average daily hot water usage 50 kg/day

System

Tilt 30 deg Diffuse sky model Isotropic
Azimuth 180 deg Irradiance inputs Beam and Diffuse
Total system flow rate 0.091056 kg/s Albedo 0.2 0.1
Working fluid Water Total system collector area 2.98 m²
Number of collectors 1 Rated system size 1.709 kW

Shading

Shading losses Edit shading... Open 3D shade calculator...

System Availability

Edit losses... Constant loss: 0.0 %
Hourly losses: None
Custom periods: None

Collector

☒ Enter user-defined parameters ☐ Choose from library

User-defined collector

Collector area 2.98 m²
FRta 0.689
FRUL 3.85 W/m².C
Incidence angle modifier 0.2
Test fluid Water
Test flow 0.045528 kg/s

Filter: Name

Name	SRCC Number	Type	Area	IAM	FRta	FRUL	Test Fluid	Te
Heliodyne Inc. Gobi 408 001	2007027C	Glazed Flat-Plate	2.99	-0...	0.73	3.41	0	0.0
Heliodyne Inc. Gobi 406 001	2007027B	Glazed Flat-Plate	2.5	-0...	0.726	3.4	0	0.0
Heliodyne Inc. Gobi 336 001	2007027A	Glazed Flat-Plate	2.49	-0...	0.725	3.24	0	0.0
Heliodyne Inc. Gobi 406 002	1981085G	Glazed Flat-Plate	2.5	0.09	0.719	5.31	0	0.0
Heliodyne Inc. Gobi 410 002	1981085D	Glazed Flat-Plate	3.73	0.09	0.719	5.31	0	0.0
Heliodyne Inc. Gobi 408 002	1981085C	Glazed Flat-Plate	3	0.09	0.719	5.31	0	0.0
Heliodyne Inc. Gobi 404 001	2007027E	Glazed Flat-Plate	1.52	-0...	0.713	3.38	0	0.0

4. Go to Financial Parameters. Set the Cost to 2000 \$ (1,60,000 ₹).

SAM 2021.12.2

File Add untitled Help

Solar water, LCOE Calculator

Location and Resource

Solar Water Heating

Financial Parameters

LCOE Calculator

The fixed-charge rate method of calculating the levelized cost of energy simplifies time-dependent calculations and is appropriate for market-level analysis such as for the NREL Annual Technology Baseline, or for very preliminary project analysis. The cash flow method of SAM's other financial models is more suitable for more detailed project analysis. See Help for details.

Capital and Operating Costs

System capacity: 1.709 kW

☐ Enter costs in \$ ☒ Enter costs in \$/kW

Capital cost: 1.00 2,000.00

Fixed operating cost (annual): 0.00 50.00

Variable operating cost: 0.0000 \$/kWh

Financial Assumptions

☒ Enter fixed charge rate ☐ Calculate fixed charge rate

Fixed charge rate (real): 0.098 Analysis period: 20 years Fixed charge rate (FCR): 0.098

Inflation rate: 2.5 %/year FCR = CRF · PFF · CFF (see below)

Internal rate of return (nominal): 13 %/year

Project term debt: 60 % of capital cost

Nominal debt interest rate: 4 %/year

Effective tax rate: 28 %/year

Depreciation schedule: Edit... % of capital cost

Annual cost during construction: 100 % of capital cost

Nominal construction interest rate: 3.5 %/year

Reference Values

Capital recovery factor (CRF): 0.083 Capital cost (CC): 3,418.06 \$

Project financing factor (PFF): 1.127 Fixed operating cost (FOC): 85.45 \$

Construction financing factor (CFF): 1.024 Variable operating cost (VOC): 0.00 \$/kWh

LCOE = (FCR · CC + FOC) / Annual Energy + VOC WACC (for reference only): 0.054

Simulate >

Parametrics Stochastic

P50 / P90 Macros

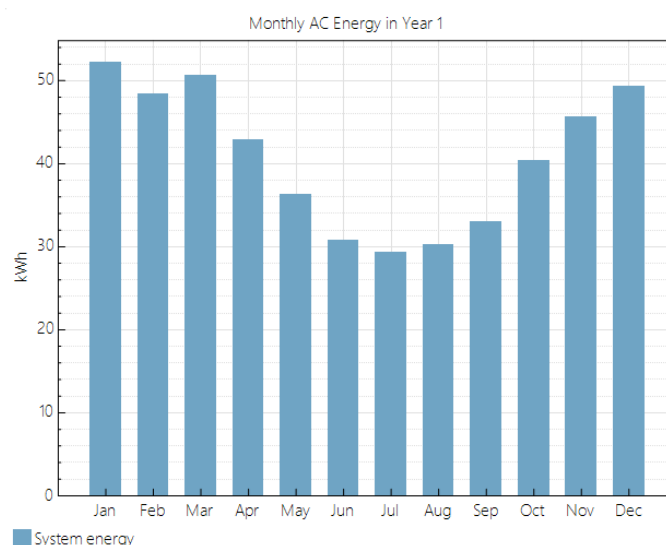
5. Stimulate and save results.

6. Repeat steps 3,4 and 5 for different values of average daily hot water usage (values to betaken as 100,150,200,250 and 300 kg/Day).

Observation:

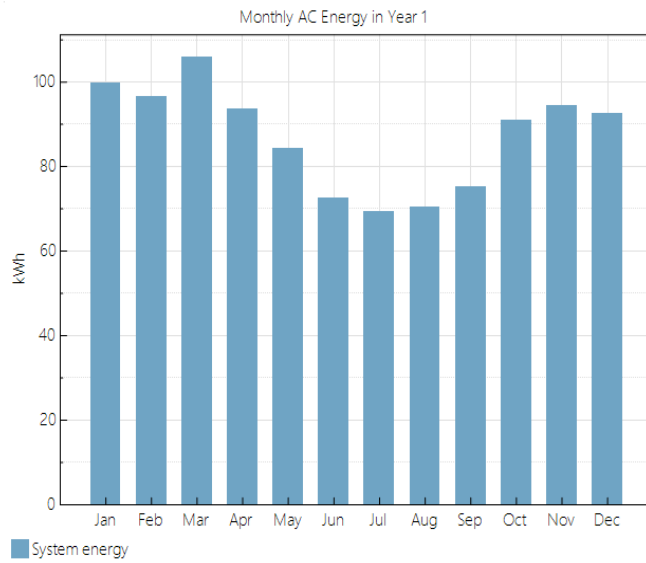
- For 50 Kg/Day

Metric	Value
Annual AC energy saved (year 1)	489 kWh
Solar fraction (year 1)	0.78
Aux with solar (year 1)	12.5 kWh
Aux without solar (year 1)	630.2 kWh
Capacity factor (year 1)	3.3%
LCOE Levelized cost of energy	85.98 ¢/kWh



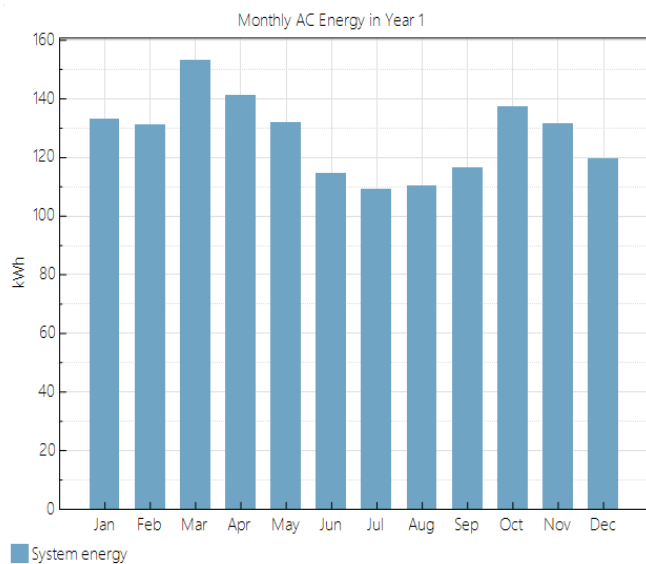
- For 100 Kg/Day

Metric	Value
Annual AC energy saved (year 1)	1,046 kWh
Solar fraction (year 1)	0.83
Aux with solar (year 1)	77.1 kWh
Aux without solar (year 1)	1,260.4 kWh
Capacity factor (year 1)	7.0%
LCOE Levelized cost of energy	40.21 ¢/kWh



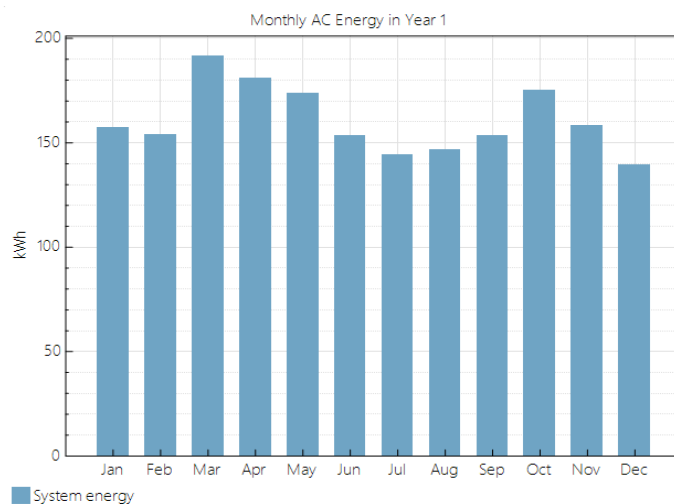
- For 150 Kg/Day

Metric	Value
Annual AC energy saved (year 1)	1,528 kWh
Solar fraction (year 1)	0.81
Aux with solar (year 1)	220.5 kWh
Aux without solar (year 1)	1,890.6 kWh
Capacity factor (year 1)	10.2%
LCOE Levelized cost of energy	27.51 ¢/kWh



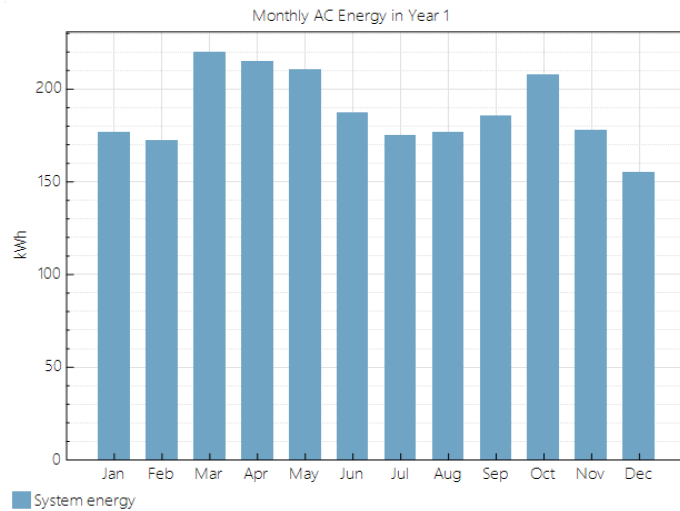
- For 200 Kg/Day

Metric	Value
Annual AC energy saved (year 1)	1,928 kWh
Solar fraction (year 1)	0.76
Aux with solar (year 1)	448.2 kWh
Aux without solar (year 1)	2,520.8 kWh
Capacity factor (year 1)	12.9%
LCOE Levelized cost of energy	21.81 ¢/kWh



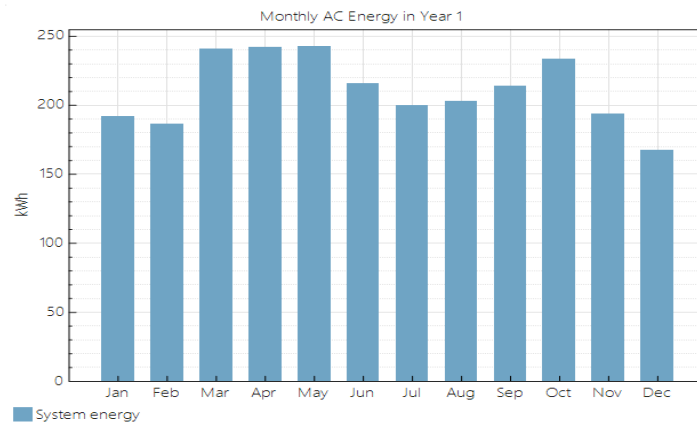
- For 250 Kg/Day

Metric	Value
Annual AC energy saved (year 1)	2,258 kWh
Solar fraction (year 1)	0.72
Aux with solar (year 1)	745.7 kWh
Aux without solar (year 1)	3,151.0 kWh
Capacity factor (year 1)	15.1%
LCOE Levelized cost of energy	18.62 ¢/kWh



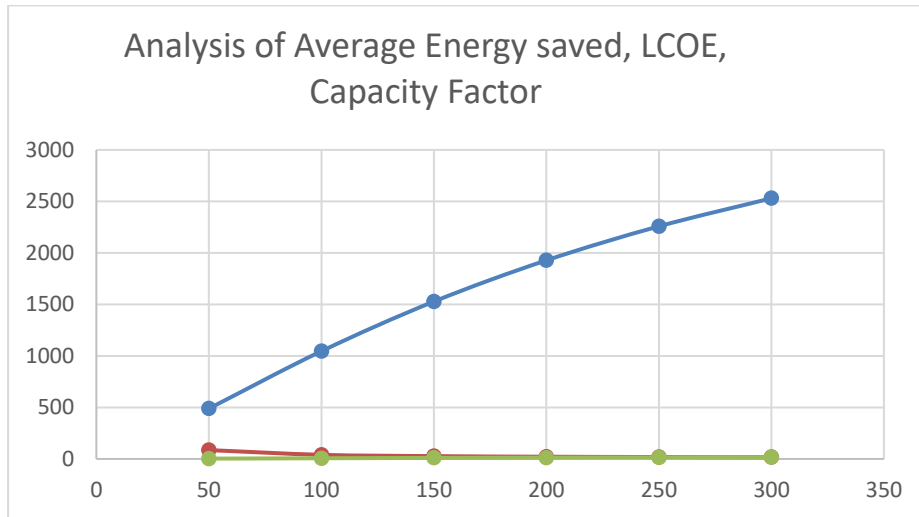
- For 300 Kg/Day

Metric	Value
Annual AC energy saved (year 1)	2,530 kWh
Solar fraction (year 1)	0.67
Aux with solar (year 1)	1,102.0 kWh
Aux without solar (year 1)	3,781.2 kWh
Capacity factor (year 1)	16.9%
LCOE Levelized cost of energy	16.62 ¢/kWh



Result:

Average Daily Hot Water usage (kg/Day)	Annual Energy Saved (kWh)	Levelized Cost of Energy (LCOE) (\$/kWh)	Capacity Factor (Percentage)
50	489	85.98	3.3
100	1046	40.21	7
150	1528	27.51	10.2
200	1928	21.81	12.9
250	2258	18.62	15.1
300	2530	16.62	16.9



Discussion and Conclusions:

- When the average water usage is 50 kg/Day, the annual saved energy is 489 kWh and at average water usage of 300 kg/Day, the energy saved annually is 2530 kWh. On observing the trend, we can say that the annual energy saved increases with increase in the average daily hot water usage.
- The Levelized Cost of Energy (LCOE) at water usage of 50 and 300 kg/Day are 85.98 and 16.62 \$/kWh respectively. Therefore, we can say that the LCOE values decrease with increase in daily water usage.
- The capacity factor increases with more hot water usage. At water usage of 50 and 300 kg/Day, the values of capacity factor are 3.3 and 16.9 respectively.