

Theoretical and Simulation Study of 50 KW PV System

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KEYWORDS

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ABSTRACT

Photovoltaic system and lithium batteries are the main focus of this research. This paper have discussed a Photovoltaic system with 50 KW capacity with and without energy storage, and compared two types of batteries Lithium cobalt oxide (LCO) and Lithium titanate oxide (LTO). In this paper, we have discussed and analyz data for monthly energy production of PV, LCO, and LTO, Annually energy production of PV, LCO, and LTC, Monthly energy and load of PV, LCO, and LTO. For the energy loss and electricity saving analysis, we have provided the comparision with data of Cash flow after tax of PV, LCO, and LTO, Energy loss of PV, LCO, and LTO. The concluded results based on the produce from SAM program. This is an innovative based idea, and this research will open the new room for new researchers and scholars.

1. Introduction

In this century the carbon dioxide emission increase to reach high level which make the people thinking how to decrease the carbon dioxide emission to the normal level, one of the solutions was to replace the energy source from fossil fuel with the renewable energy, one of the famous types of the renewable energy is the solar energy by using PV, this research will show the results for a PV system in Riyadh [1-4]. In this paper, the monthly energy production of PV, LCO, and LTO, Annually energy production of PV, LCO, and LTC, Monthly energy and load of PV, LCO, and LTO has been analyzed [5]. Photovoltaic system with 50 KW capacity with and without energy storage, and compared two types of batteries Lithium cobalt oxide (LCO) and Lithium titanate oxide (LTO) has been addressed [6-7]. The comparison with world wide data of Cash flow after tax of PV, LCO, and LTO, Energy loss of PV, LCO, and LTO has been discussed in respect of energy loss and electricity saving analysis. For the validation process we have used SAM program. In these analysis, we have identify that PV system can produce huge energy which can help meet the energy demand, but we cannot use the PV if the cost of the PV is high and the price of the electricity is low there will be no benefit from using the PV, so more research is needed to increase the efficiency and reduce the cost of PV. In addition, if the battery was too expensive it will make the total cost of the system high which mean the system will not be efficient and that is why we need to improve the batteries and make it more efficient. Comparing between LCO battery and LTO battery LTO was better in all the comparing except the cash flow after tax, and LTO has more cell capacity than LCO (LTO = 12 Ah, LCO = 2.55 Ah).

2. Result and discussion

For the monthly energy production PV alone and PV with energy storage they have almost the same energy production for example if we see first month PV gives 5422.65 while PV with energy storage gives 5410.67 and

5410.73. Comparing between PV with LCO battery and PV with LTO battery PV with LTO battery gives energy more slightly see Table.1-4

Table.1. monthly energy production of PV, LCO, and LTO

Monthly energy production PV	Monthly energy production LCO		Monthly energy production LTO	
	AC energy		AC energy	AC energy
0	4332.86	0	4301.46	4303.13
1	5422.65	1	5410.67	5410.73
2	6102.17	2	6084.41	6084.48
3	5849.83	3	5845.14	5845.18
4	5963.97	4	5952.26	5952.34
5	6391.78	5	6362.91	6363.1
6	6592.61	6	6577.88	6578.27
7	6362.12	7	6338.86	6339.15
8	6331.87	8	6296.93	6297.14
9	6190.03	9	6177.08	6177.21
10	4724.77	10	4713.69	4713.77
11	4967.7	11	4953.79	4953.88

Table.2. Monthly energy production of PV graph

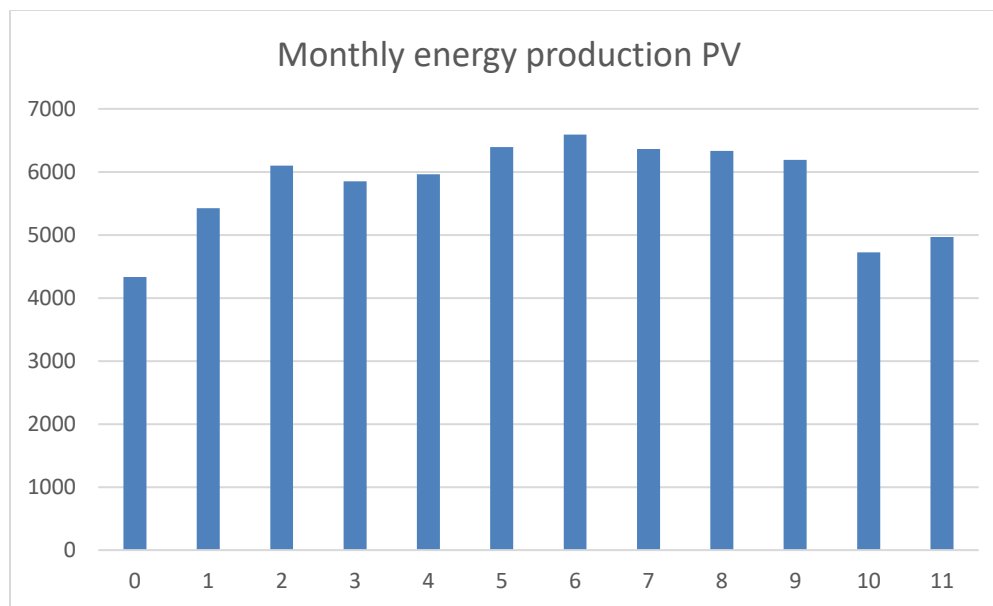


Table.3. Monthly energy production of LCO graph

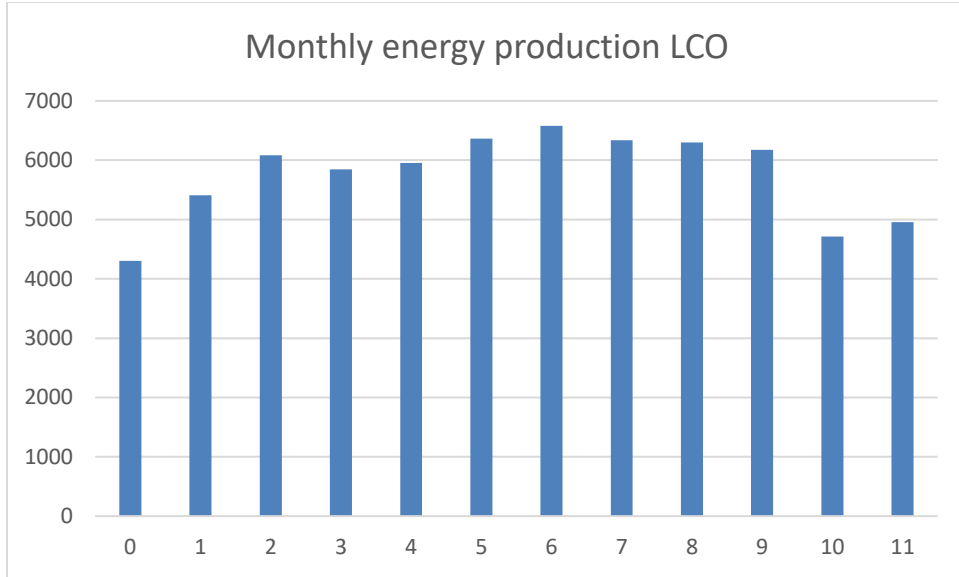
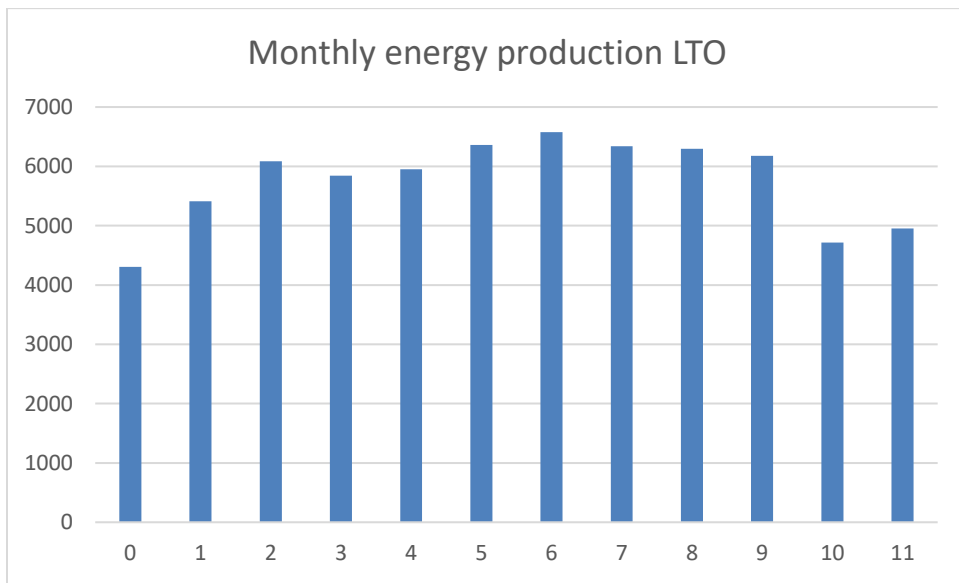


Table.4. Monthly energy production of LTO graph



For the annually energy production PV alone produce more energy (slightly) than PV with energy storage for example if we see first year PV gives 69232.4 while PV with energy storage gives 69015.1 and 69018.4. Comparing between PV with LCO battery and PV with LTO battery both almost gives same energy production [see Table.5-8](#)

Table.5. Annually energy production of PV, LCO, and LTC

Annual energy production PV		Annual energy production LCO		Annual energy production LTC	
Year	Energy	Year	Energy	Year	Energy
0	0	0	0	0	0
1	69232.4	1	69015.1	1	69018.4

2	68878.5	2	68677.1	2	68679
3	68526.4	3	68324.6	3	68326.6
4	68176	4	67973.9	4	67975.9
5	67827.3	5	67625	5	67627
6	67480.2	6	67277.7	6	67279.9
7	67134.9	7	66932.2	7	66934.4
8	66791.2	8	66588.4	8	66590.7
9	66449.3	9	66246.3	9	66248.6
10	66109	10	65906	10	65908.3
11	65770.4	11	65567.2	11	65569.6
12	65433.5	12	65230.2	12	65232.6
13	65098.1	13	64894.7	13	64897.2
14	64764.4	14	64560.9	14	64563.4
15	64432.4	15	64228.7	15	64231.3
16	64101.9	16	63898.2	16	63900.7
17	63773	17	63569.2	17	63571.8
18	63445.8	18	63241.9	18	63244.5
19	63120.2	19	62916.1	19	62918.8
20	62796.1	20	62592	20	62594.7
21	62473.7	21	62269.5	21	62272.3
22	62152.8	22	61948.5	22	61951.3
23	61833.5	23	61629.1	23	61631.9
24	61515.7	24	61311.5	24	61314.1
25	61199.5	25	60995.1	25	60997.9

Table.6. Monthly energy production of PV graph

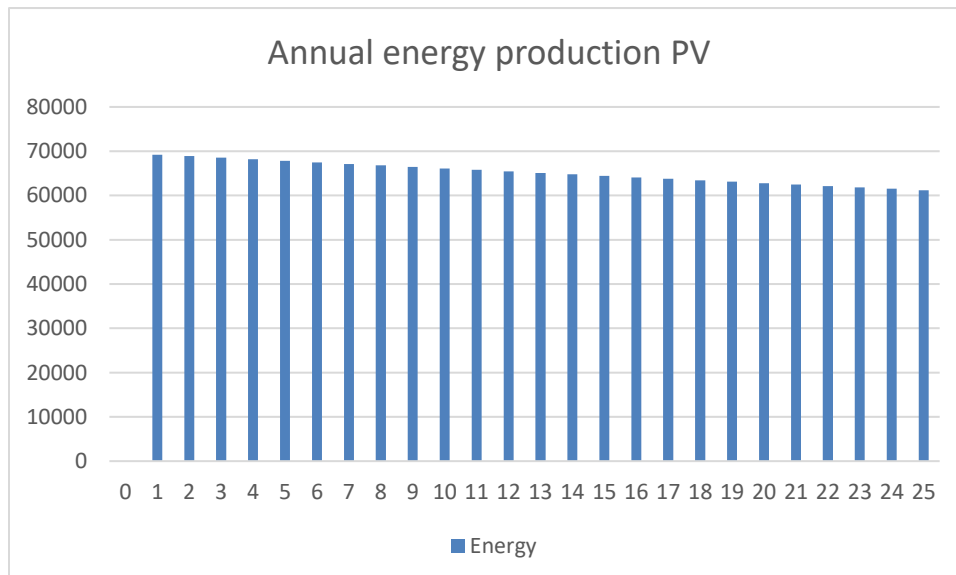


Table.7. Monthly energy production of LCO graph

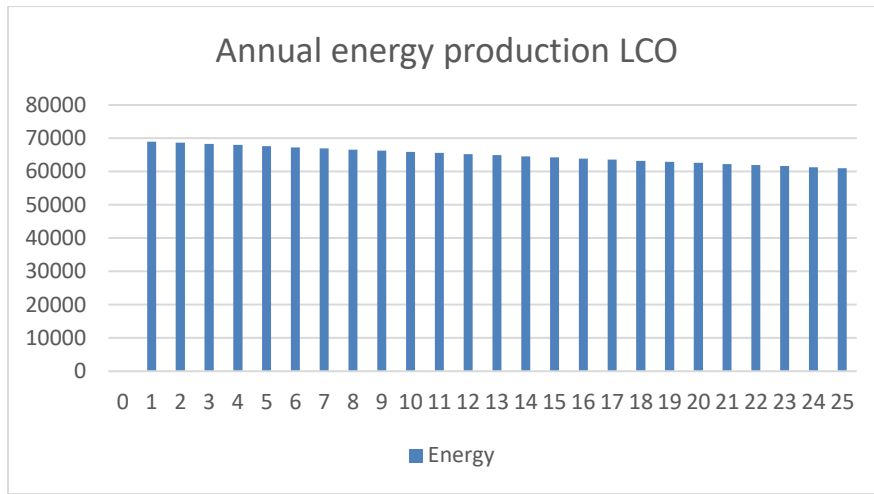
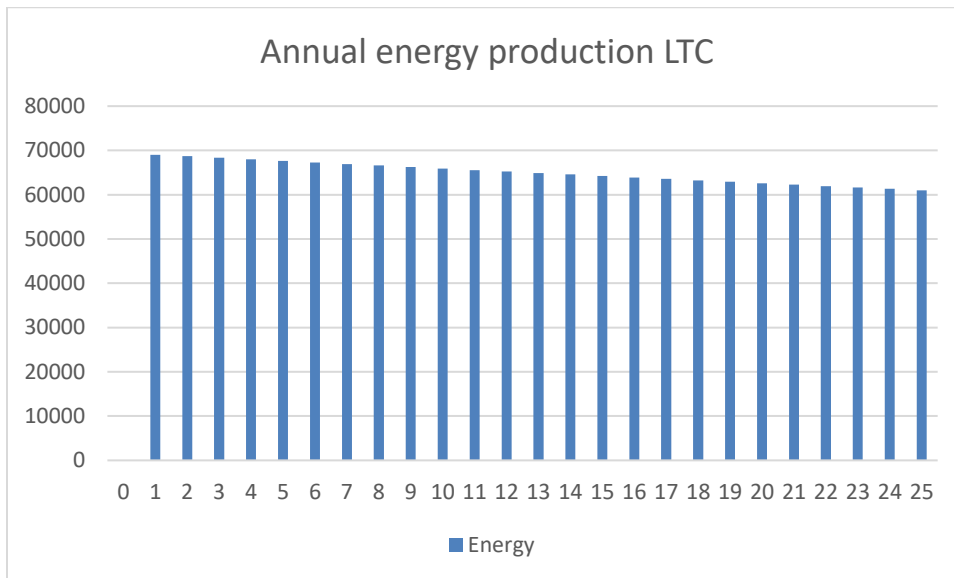


Table.8. Monthly energy production of LTC graph



The tables and graphs show that PV alone gives slightly more AC energy comparing with PV with energy storage for example at month number 11 PV alone has 4967.7 energy and 731.813 load while PV with energy storage has 4945.49 and 4953.88 energy and 731.813 load same as PV alone. Comparing between PV with LCO battery and PV with LTO battery they have same load but PV with LTO batter gives slightly more AC energy see Table. 9-12.

Table.9. Monthly energy and load of PV, LCO, and LTO

Monthly energy and load PV			Monthly energy and load LCO			Monthly energy and load LTO		
	AC energy	Electricity load	AC energy	Electricity load	AC energy	Electricity load	AC energy	Electricity load
0	4301.46	752.186	0	4315.75	752.186	0	4303.13	752.186

1	5410.67	642.382	1	5407.1	642.382	1	5410.73	642.382
2	6084.41	647.755	2	6081.45	647.755	2	6084.48	647.755
3	5845.14	643.76	3	5841.74	643.76	3	5845.18	643.76
4	5952.26	777.222	4	5946.51	777.222	4	5952.34	777.222
5	6362.91	1151.7	5	6360.53	1151.7	5	6363.1	1151.7
6	6577.88	1594.78	6	6577.74	1594.78	6	6578.27	1594.78
7	6338.86	1393.36	7	6338.08	1393.36	7	6339.15	1393.36
8	6296.93	1016.16	8	6302.95	1016.16	8	6297.14	1016.16
9	6177.08	837.847	9	6174.24	837.847	9	6177.21	837.847
10	4713.69	640.379	10	4707.34	640.379	10	4713.77	640.379
11	4953.79	731.813	11	4945.49	731.813	11	4953.88	731.813

Table.10. Monthly energy and load of PV graph

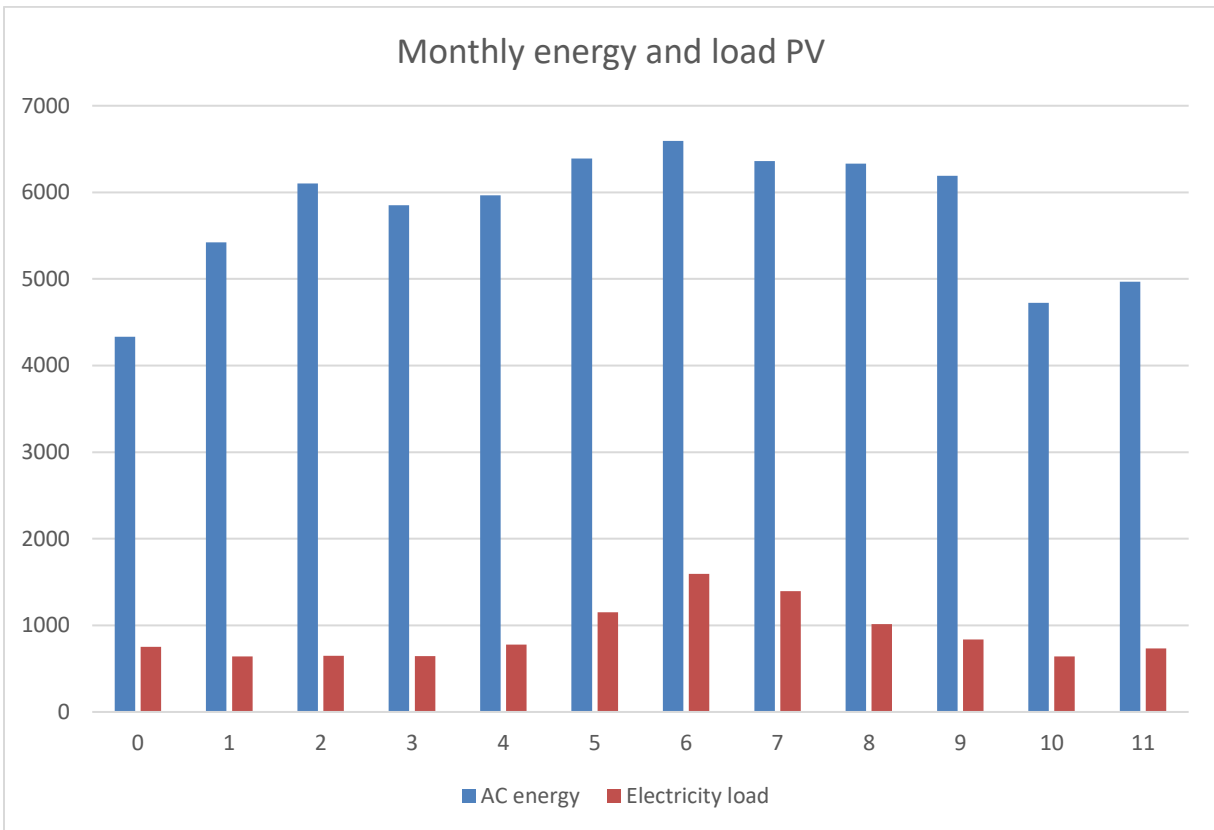


Table.11. Monthly energy and load of LCO graph

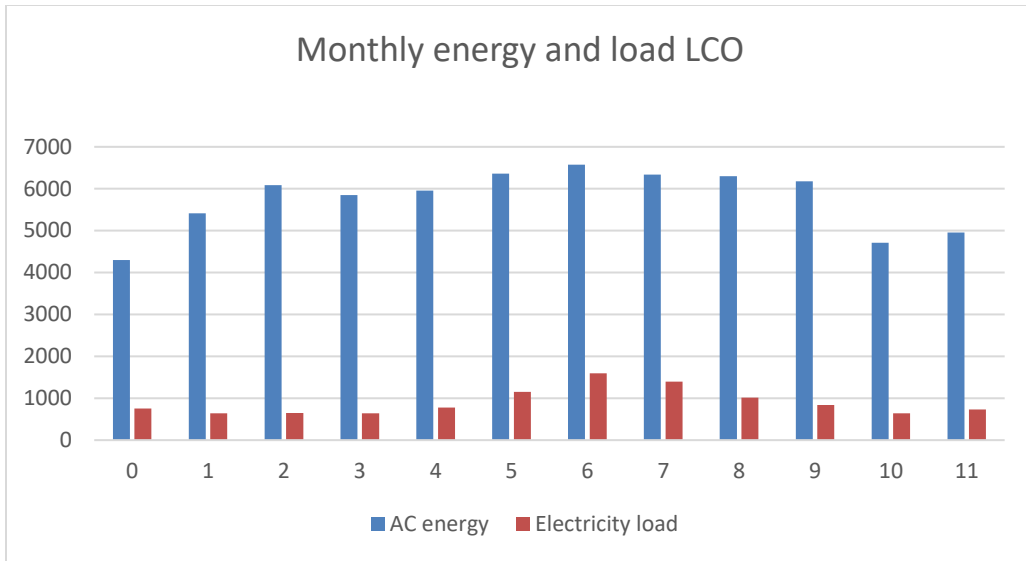
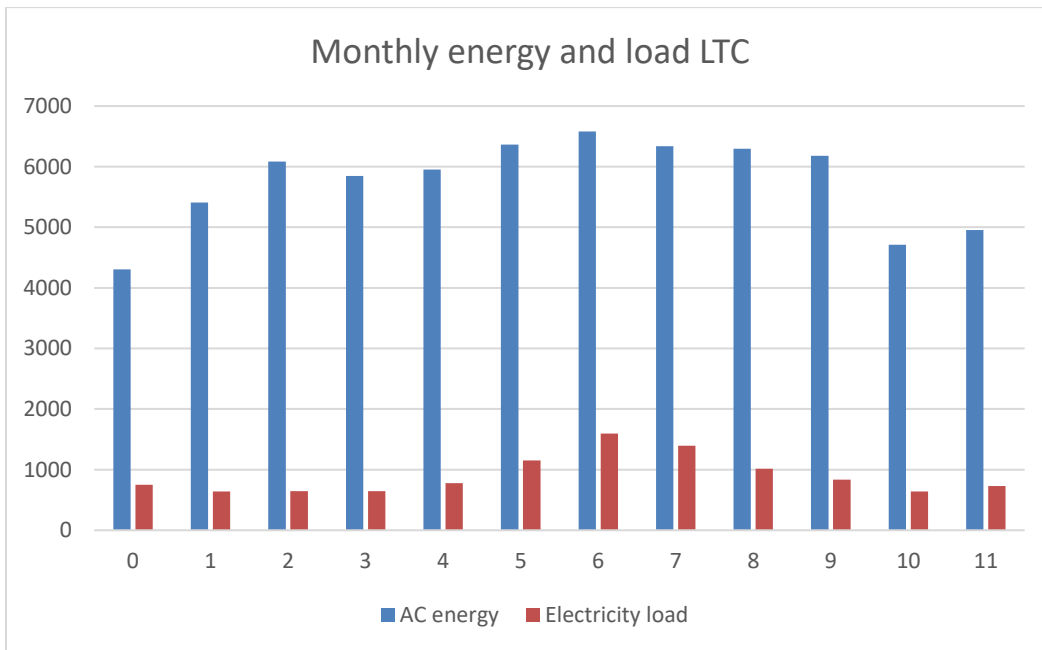


Table.12. Monthly energy and load of LTC graph



2.1. Electricity saving

For the PV alone the Value of electricity savings is less than the PV with energy storage for example in month number 25 the value for PV alone is 1647 and PV with energy storage is 2995 and 2995. The electricity saving for PV with LCO battery is same as PV with LTO battery.

2.2. Cash flow after tax

Table.13. Cash flow after tax of PV, LCO, and LTO

Cache flow after tax PV	Cash flow after tax LCO	Cash flow after tax LTO
After-tax cash flow	After-tax cash flow	After-tax cash flow

0	0	0	0	0	0
1	26164.2	1	41877.1	1	41797.5
2	-9559.78	2	-11743.5	2	-11720.7
3	-9623.09	3	-11798.6	3	-11775.7
4	-9688.8	4	-11856.7	4	-11833.6
5	-9757	5	-11917.7	5	-11894.6
6	-9827.8	6	-11982	6	-11958.7
7	-9901.3	7	-12049.5	7	-12026.1
8	-9977.62	8	-12120.6	8	-12097.1
9	-10056.9	9	-12195.4	9	-12171.7
10	-10139.2	10	-12274.1	10	-12250.2
11	-10224.7	11	-12356.9	11	-12332.8
12	-10313.5	12	-12444	12	-12419.7
13	-10405.8	13	-12535.5	13	-12511.1
14	-10501.7	14	-12631.8	14	-12607.2
15	-10601.3	15	-12733.1	15	-12708.3
16	-10705	16	-12839.6	16	-12814.6
17	-10812.7	17	-12951.6	17	-12926.3
18	-10924.7	18	-13069.4	18	-13043.9
19	-11041.1	19	-13193.3	19	-13167.5
20	-11162.2	20	-13323.5	20	-13297.5
21	-11288.2	21	-13460.4	21	-13434.1
22	-11419.3	22	-13604.4	22	-13577.8
23	-11555.6	23	-13755.8	23	-13728.9
24	-11697.5	24	-13914.9	24	-13887.7
25	-11845.2	25	-14082.2	25	-14054.7

Table.14. After tax cash flow of PV graph

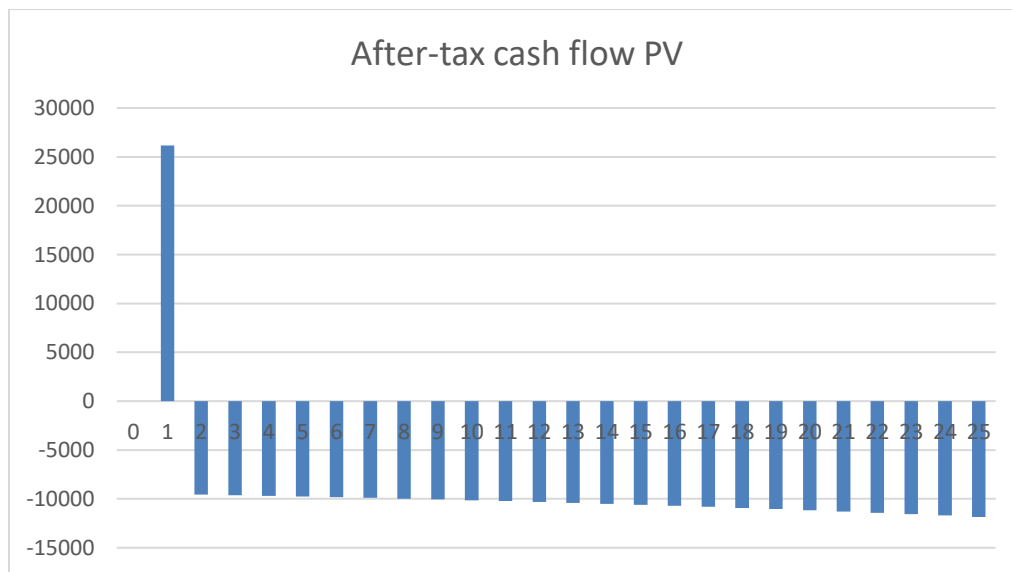


Table.15. After tax cash flow of LCO graph

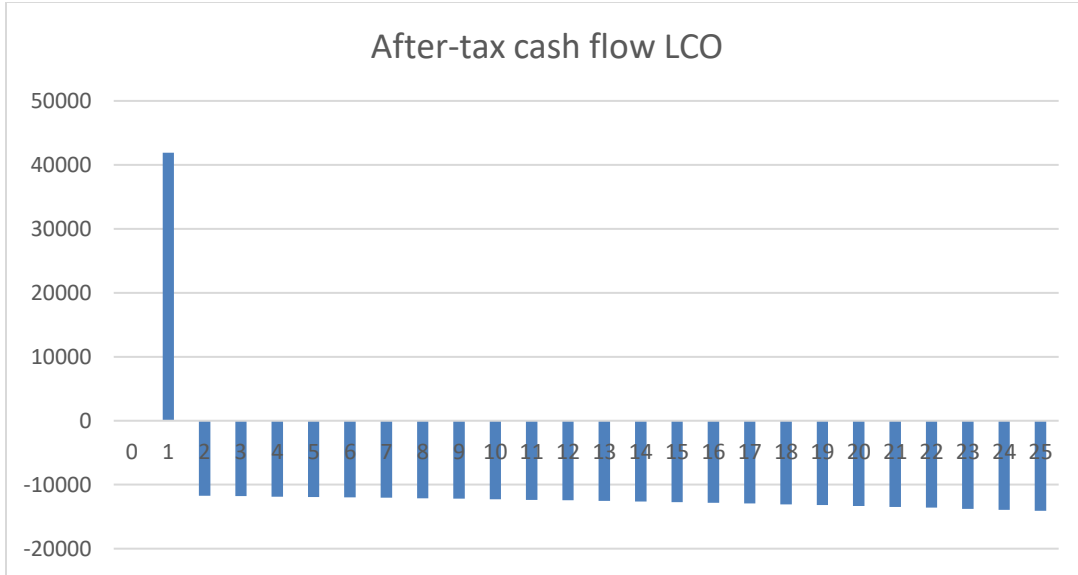
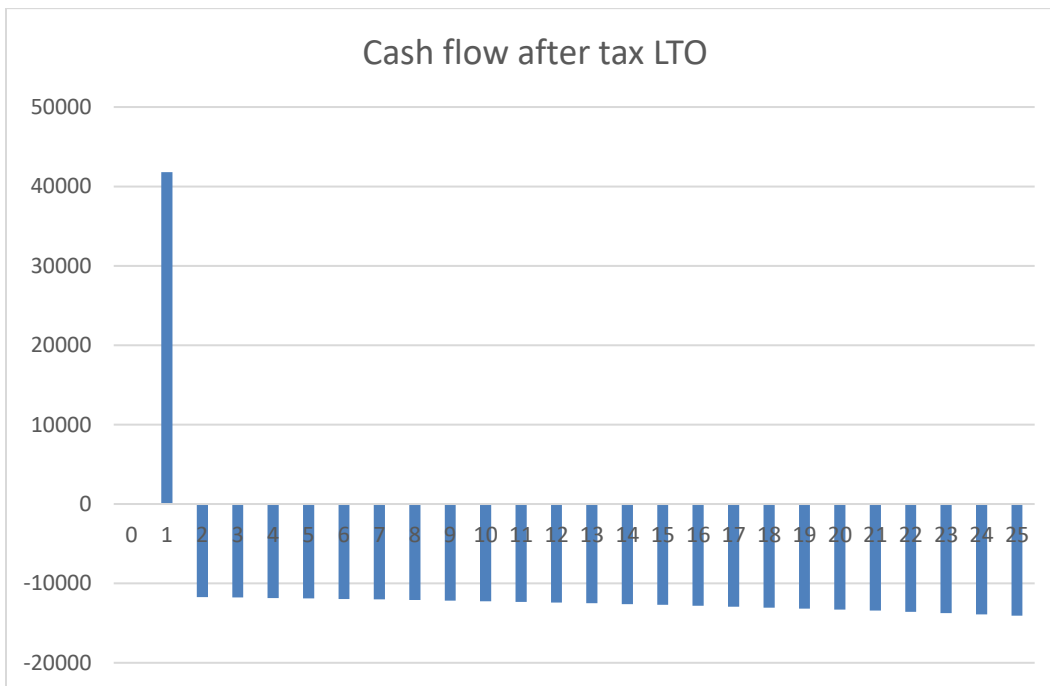


Table.16. After tax cash flow of LTO graph



Graphs and tables show that the cash flow for PV alone has less income at first and less out come after that than PV with energy storage. The graphs and tables show that PV with LCO battery and PV with LTO battery cash flow after tax are almost same at first then PV with LCO saves more money see [Table.13-16](#)

2.3. Energy loss

The PV alone has less losses than the PV with energy storage because the battery adds more loss, and most of the losses come from:

- inverter clipping
- module
- soiling

PV with LCO battery has more losses than PV with LTO battery as we can see from the [Fig.1-3. And Table.17](#)

Table.17. Energy loss of PV, LCO, and LTO

Energy Loss PV		Energy loss LCO		Energy loss	
Nominal POA (KWh)	649100	Nominal POA (KWh)	649100	Nominal POA (KWh)	649100
Shading	0	Shading	0	Shading	0
Soiling	-5%	Soiling	-5%	Soiling	-5%
Reflection	-3.09%	Reflection	-3.09%	Reflection	-3.09%
Bifacil	0	Bifacil	0	Bifacil	0
Nominal DC energy (KWh)	92839	Nominal DC energy (KWh)	92839	Nominal DC energy (KWh)	92839
Snow	0	Snow	0	Snow	0
Module deviation from STC	-8.37%	Module	-8.37%	Module	-8.37%
Inverter MPPT clipping	-9.01%	Inverter MPPT clipping	-9.01%	Inverter MPPT clipping	-9.01%
Module mismatch	-2%	Module mismatch	-2%	Module mismatch	-2%
Diodes and connection	-0.50%	Diodes and connection	-0.50%	Diodes and connection	-0.50%
DC wiring	0.00%	DC wiring	-2.00%	DC wiring	-2.00%
Tracking error	0.00%	Tracking error	0.00%	Tracking error	0.00%
Nameplate	0.00%	Nameplate	0.00%	Nameplate	0.00%
DC power optimizer	0.00%	DC power optimizer	0.00%	DC power optimizer	0.00%
DC availability and curtailment	0.00%	DC availability and curtailment	0.00%	DC availability and curtailment	0.00%
DC lifetime daily losses-year one	0.00%	DC lifetime daily losses-year one	0.00%	DC lifetime daily losses-year one	0.00%
Net DC energy (KWh)	732.97	Net DC energy (KWh)	73297.00	Net DC energy (KWh)	73297.00
Inverter power clipping	0.00%	Inverter power clipping	0.00%	Inverter power clipping	0.00%
Inverter power consumption	-1.93%	Inverter power consumption	-1.93%	Inverter power consumption	-1.93%
Inverter nightttime consumption	-0.12%	Inverter nightttime consumption	-0.12%	Inverter nightttime consumption	-0.12%
Inviter efficiency	-2.60%	Inviter efficiency	-2.60%	Inviter efficiency	-2.60%

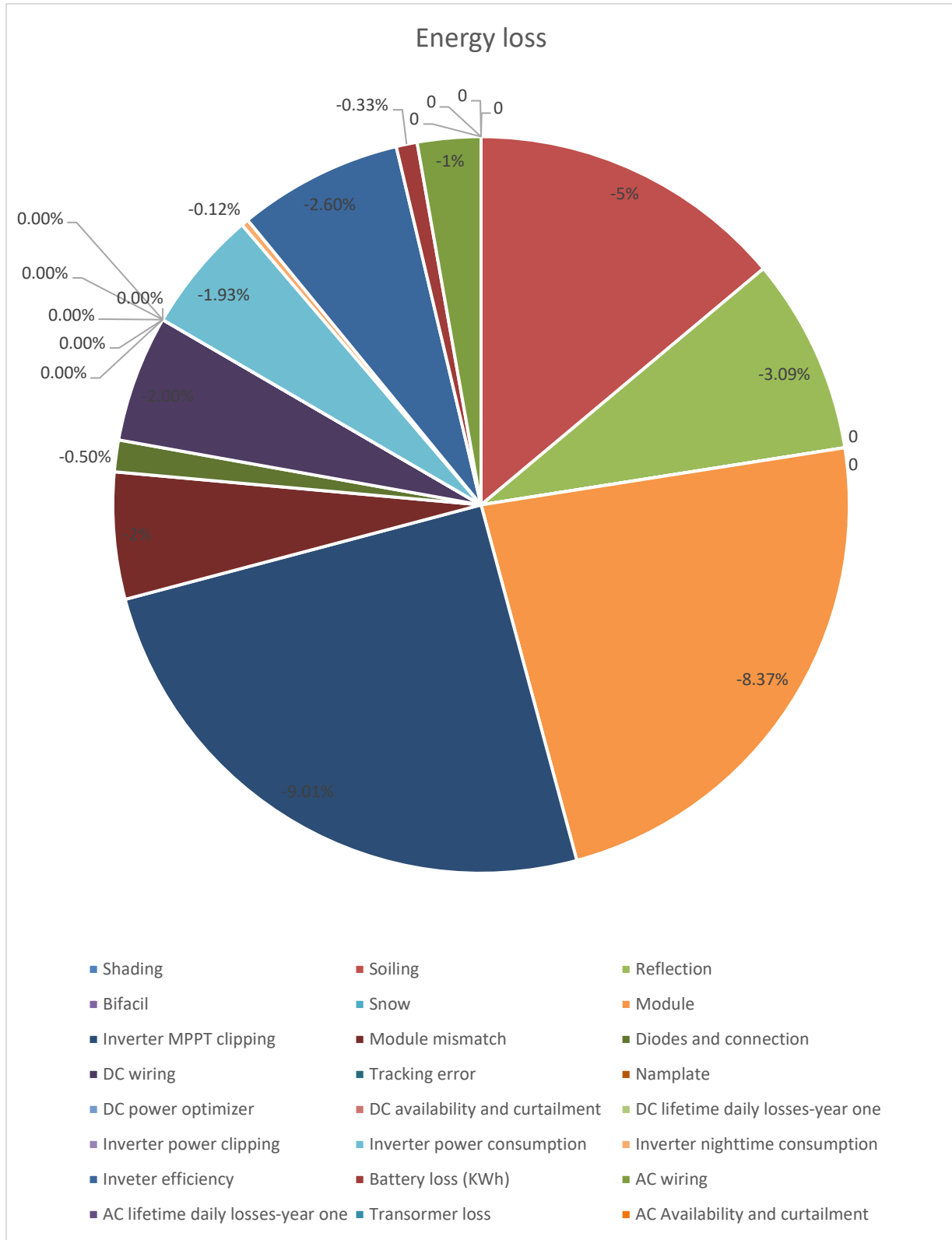
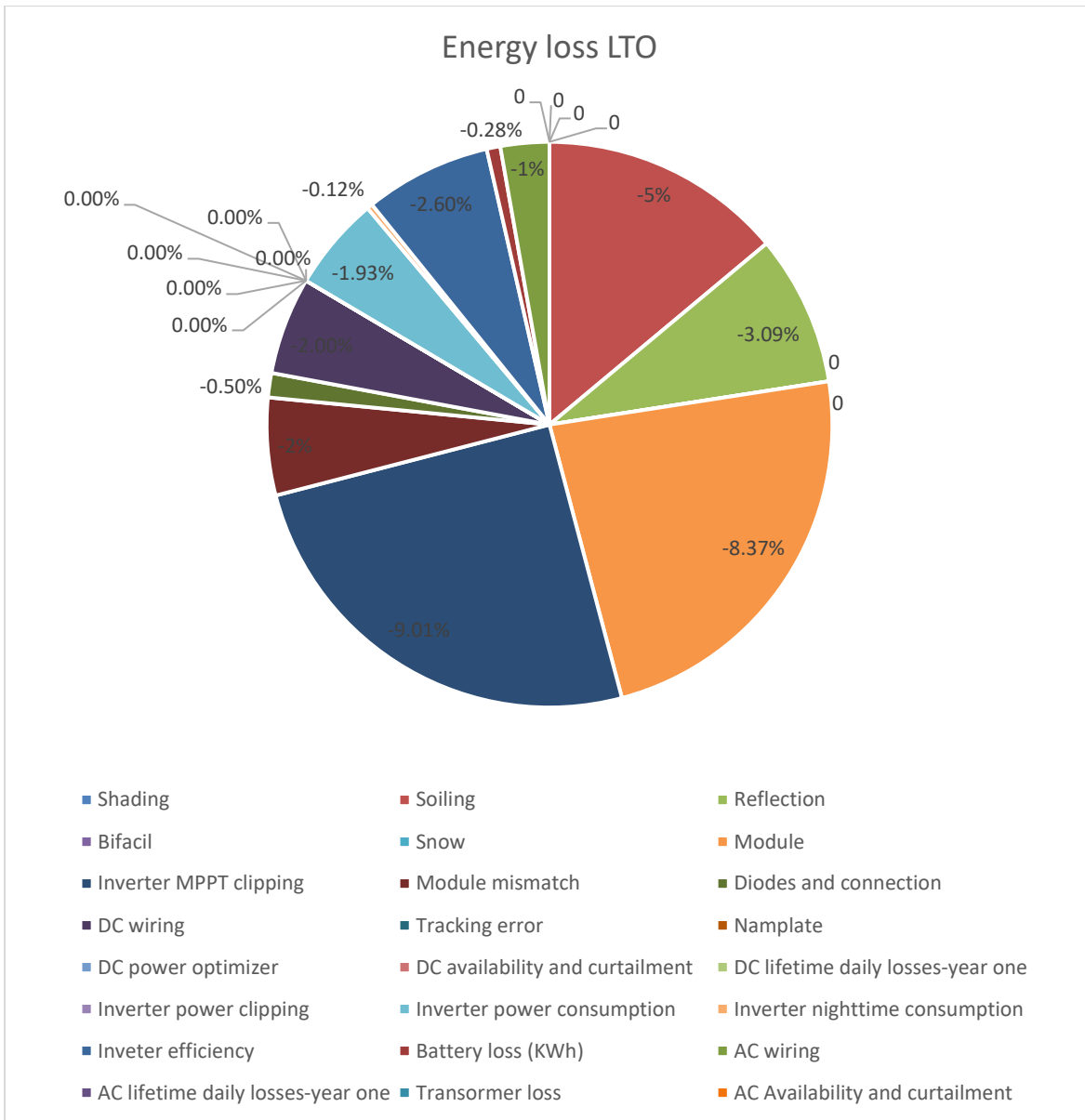


Figure.3. Pie diagram of energy losses data LTO



3. Conclusion

From summary [table.18](#) PV without energy storage has higher annual energy and energy yield and better performance and has less capital cost but the bill with the system for PV with energy storage is less than without energy storage.

a) PV alone:

PV system can produce huge energy which can help meet the energy demand, but we cannot use the PV if the cost of the PV is high and the price of the electricity is low there will be no benefit from using the PV, so more research is needed to increase the efficiency and reduce the cost of PV. When the PV used where the peak demand is in

same time when PV give maximum energy the benefit from PV will increase and as the time between them increase the benefit will decrease because most of the energy from the PV, we will not use it.

b) PV with energy storage:

PV with energy storage help get benefit from PV even at night or if there is shift between peak demand and maximum power time of the PV. If the battery was too expensive it will make the total cost of the system high which mean the system will not be efficient and that is why we need to improve the batteries and make it more efficient. Comparing between LCO battery and LTO battery LTO was better in all the comparing except the cash flow after tax, and LTO has more cell capacity than LCO (LTO = 12 Ah, LCO = 2.55 Ah).

Table.18. Summary of PV, LCO, and LTO

Summery table PV		Summery table LCO		Summery table LTO	
Metric	Value	Metric	Value	Metric	Value
Annual energy (year 1)	69,232 kWh	Annual energy (year 1)	69,015 kWh	Annual energy (year 1)	69,018 kWh
Capacity factor (year 1)	15.70%	Capacity factor (year 1)	15.60%	Capacity factor (year 1)	15.60%
Energy yield (year 1)	1,374 kWh/kW	Energy yield (year 1)	1,369 kWh/kW	Energy yield (year 1)	1,369 kWh/kW
Performance ratio (year 1)	0.69	Performance ratio (year 1)	0.68	Performance ratio (year 1)	0.68
-	-	Battery roundtrip efficiency	91.76%	Battery roundtrip efficiency	91.85%
-	-	Battery charge energy from system	100.00%	Battery charge energy from system	100.00%
Levelized COE (nominal)	11.90 c/kWh	Levelized COE (nominal)	13.99 c/kWh	Levelized COE (nominal)	13.96 c/kWh
Levelized COE (real)	9.50 c/kWh	Levelized COE (real)	11.17 c/kWh	Levelized COE (real)	11.15 c/kWh
Electricity bill without system (year 1)	\$1,514	Electricity bill without system (year 1)	\$1,777	Electricity bill without system (year 1)	\$1,777
Electricity bill with system (year 1)	\$570	Electricity bill with system (year 1)	\$121	Electricity bill with system (year 1)	\$121
Net savings with system (year 1)	\$944	Net savings with system (year 1)	\$1,656	Net savings with system (year 1)	\$1,656
Net present value	-\$66,126	Net present value	-\$70,815	Net present value	-\$70,675
Simple payback period	NaN	Simple payback period	NaN	Simple payback period	NaN
Discounted payback period	NaN	Discounted payback period	NaN	Discounted payback period	NaN
Net capital cost	\$137,165	Net capital cost	\$206,031	Net capital cost	\$205,638
Equity	\$0	Equity	\$0	Equity	\$0
Debt	\$137,165	Debt	\$206,031	Debt	\$205,638

4. Acknowledgement

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5. References

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