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An Innovative Zero-Emission Energy Model for a Coastal Village in Southern Myanmar

Prof. Aung Ze Ya[1] and Prof. Aung Ze Ya[2]

[1] Yangon Technological University

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Abstract

Myanmar boosts the Renewables harvesting with On-Grid and Off-Grid options to implement 2030 Agenda. Reversing the degradation of the Coastal Eco-System is also the prioritized Agenda. The research and deployment of Photovoltaic (PV), Wind, and Hybrid Mini-Grids are at the initial state. This work imagined for supporting these. Thus, a village Lel Hpet, located in Palaw Township, Tanintharyi Region chose due to its blessings of PV and Wind resources. The villagers currently use the Diesel Generators for the industrial loads and the fuelwood for the cooking. These cause the negative impacts. Hence, Zero-Emission Energy Model analyzed. The total demand separated into Primary Load and Deferrable Load. The simulation innovated with four Models on the excellent platform for Energy Planning, HOMER (Hybrid Optimization of Multiple Energy Resources) Pro (version 3.11.4). Then, the Best Model is selected. Its simulative results proved Wind is more feasible than PV on the Tanintharyi Coast, PV and Wind can compensate each other during their less generation months, and the larger Off-Grid Mini-gird is more cost-effective. The savings of the Diesel fuel usage and its costs, and the reduction of GHG (greenhouse gas) Emissions predicted. The proposed Climate-friendly, standalone PV-Wind-Battery Hybrid Mini-Grid can improves the Green penetration in Southern Myanmar.

Index terms— southern Myanmar, Tanintharyi coast, village lel hpet, HOMER Pro, zero-emission energy model, simulation, standalone PV-wind-battery hybrid mini-grid.

1 INTRODUCTION

yanmar, 40 th largest nation in the world, geographically located between 9º 32' and 28º 31' N latitude; and 92º 10' and 101º 11' E. It situated as the strategic link of South Asia and South East Asia. It covers a land area of over 676,577 square kilometers and stretches over 2280 kilometers ??3].

2 a) Myanmar's Three Coasts

Myanmar is very susceptible to extreme weather risks, landslides, sea-level rise related to air-current, and predicted future climate change. Coastal erosion and flooding are further risks which are predicted to grow. Tropical storms, occasional cyclones suffer regularly. The coastline is nearly 3000 km, extending about 1900 km from 10° to 21° North of the Equator, and 93° to 97° East of Greenwich [4].

Author: PhD, Post Doc, Honorary Professor and Honorary Doctor of Science, Professor of Department of Electrical Power Engineering, and Director of Department of Maintenance Engineering, Yangon Technological University (YTU), Myanmar. e-mails: profazyytumm10@gmail.com, dr.aungzeya010@gmail.com Unsustainable development can exacerbate the rural poverty in the coastal areas, and cause to leave the native villagers and weaken the majority of the population. Consequently, the rural population is behind the urban populations grow and prosper. Rural poverty remains the problem, and in the context of rising sea levels, and increasingly unstable weather. Coastal resilience is an issue of ever growing importance [4].

3 b) Standalone Mini-Grids in Myanmar

National Electrification Planning (NEP) of Myanmar Agenda 2030 aimed to electrify 7.2 million households, and achieve universal access to electricity by 2030. In the long term, the least cost extension of the National Grid System (NGS) included. For preelectrification, the standalone Mini-Grids and Solar Home Systems (SHS) are the options for the rural areas far from that National Grid will take many years to reach [13]. The criteria to implement the standalone Mini-Grid are the village can't electrify by the NGS in the next five to ten years, its location is at least 10 kilometers from the NGS, the sufficient demand for Mini-Grid scale, and the number of households should be 150 to 200 with the concentrated group. Large villages with high demands are preferable as a high possibility of the stronger revenue streams to achieve Sustainable Mini-Grids [9].

4 c) Motivation

The motivation of this work is to energize the village with the Innovative Hybrid System to conserve the Coastal Eco-System. Also, it targeted to promote the Rural Electrification rate by improving the Green Growth.

5 d) e) Identification of the Problems

The inhabitants are commonly using the small Diesel Generators for the water pumping and the industrial loads. All the houses apply the Compact Fluorescent Lamps (CFL) for the lightings and the fuelwood for the cookings. The hierarchical methodology is comprehensive process that involved the seven steps depicted as the pyramid in Fig. 2. The site survey is the fountain and essential work to know the real ground situation. The problems of the existing Energy access identified. Then, the appropriate Energies selected due to the potentials of the site and the priorities of the country. As the third step, the relevant technology and components chose. The load profiles predicted. The input parameters To solve above problems, the Standalone PVWind-Battery Hybrid Mini-Grid modeled in HOMER Pro.

6 Global

7 b) Selection and Inputs of the Resources

Due to the geographical location, Myanmar has a rich Solar potential, and 60% of the land area appears suitable for PV deployments [10]. Fig. 4 [11] illustrates GHI (Global Horizon Irradiation) of Myanmar. From it, it is clear that the project location has the potential of Solar PV Energy. There are a few months (June, July, and August), which cannot favor for the PV generation. Hence, PV Energy is firstly selected to harvest. The strong winds can damage not only PV modules but also the construction components. However, the positive impacts can cause the low and medium speed winds. These winds create the cooling effects on PV modules and increase the power generation [11]. Hence, the Wind potential showed in Fig. 6 is not high, but, it can be beneficial for PV system. In June, July, and August, Wind has the high potentials. Thus, Wind System can compensate the less generation of PV System in these months. This point is the advantage of PV-Wind Hybrid System. The Eco-friendly and the Energy Efficient loads are considered. To apply the effective simulationfeatures of HOMER Pro, the total demand divided into two main types, Primary Load (PL) and Deferrable Load (DL) as depicted in Fig. 7. PL is sub-divided into two types. PL1 (small) includes the LED lamps, flat TVs, and other small loads. PL2 (large) consists of the kitchen loads (the ricecookers, the cooking pots), the cooling loads (the fans, the air-coolers, and the water-coolers) and the small industrial loads listed in Table 1. DL composed of two categories. DL1 (small) contains the mobile chargers, the power banks, and the rechargeable LEDs. DL2 (large) involves the fifteen 1.5 kW water pumping loads. Based on the collected data from a site visit in January 2018, the load profiles predicted for a one Pagoda, a one Monastery, 250 households (HH), and the school, the street lightings, the water pumping loads, and the small industrial loads. The households (HH) are classified as the three groups depending on the demands. The low and high demand groups have 25 and 50 households. The medium demand group has 175 households. All demands (PL1, PL2 and DL) connected in the M3 and M4. PL1 is 108.6 kWh per day and 37.34 kW peak. PL2 is 336.14 kWh per day and 59.28 kW peak. Deferrable Load is 43 kWh per day and 28.75 kW peak.

Globally, the largest amount of GHG is significantly emitted from the fossil fuels utilizations for Electricity Generations [23]. Hence, the notable point is Diesel Mini-Grid (M4) modeled with the same demands as M3 to determine the specific amount of GHG Emissions, also, the fuel usage and the fuel cost from it.

8 f) Inputs of Main Components

The parameters of the main components of the standalone PV Mini-grid modeled in HOMER Pro.

9 RESULTS AND DISCUSSIONS

The thousands of Techno-Economic designs simulated for the four Models in HOMER Pro. Then, the optimum designs calculated with the Tabular results of two: the upper portion is the Sensitivity Cases and the lower portion is the Optimization Results as reflected in Figs. 19 to 22. The displayed results are listed for the models from the top to bottom of the optimistic to the least cost-effective options [24]. M1 to M3 connected with the different demands. Hence, the different capacities of the Architecture, the costs, system and other respective results predicted. The outcomes of M4 (the same demands as M3 with the different type of generation) reflected its consequent negative impacts. The main results of four models mentioned in Table 4. M3 can supply all demands with the lowest cost of energy (COE) among three Models of PV-Wind-Battery Hybrid. Also, it observed that COE of M3 and M4 are not much differed. Fig. 23 mentioned the evident Emissions, the six pollutants from M4. There are no Diesel fuel consumptions, Diesel fuel costs, and no impacts (zero GHG Emission) by M3. Thus, M3 is selected as the proposed system of this research. Figs. 24 to 33 revealed the graphical results of M3.

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Figure 1: Fig. 1

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Figure 2: Fig. 1 :

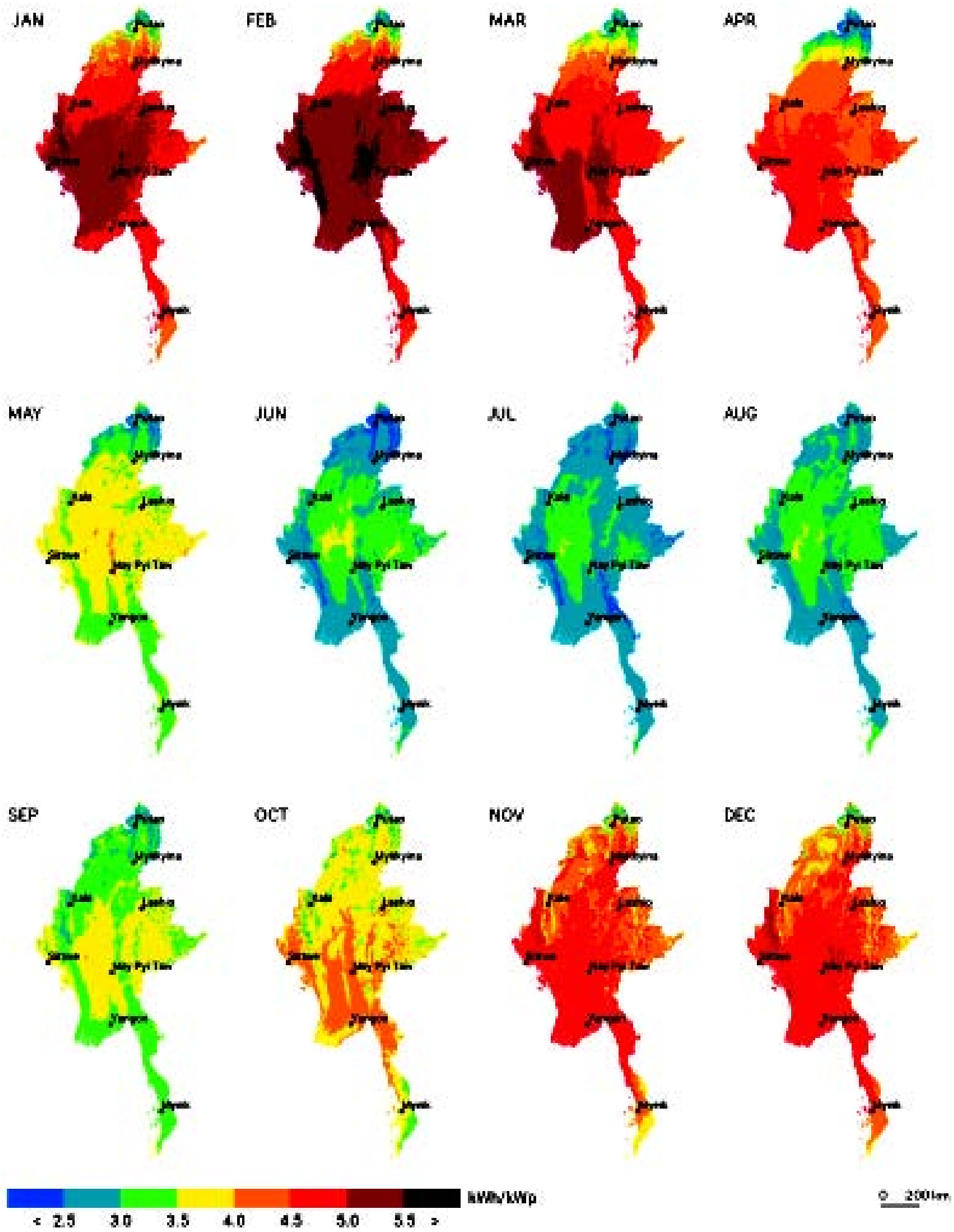
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Figure 3: F

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Figure 4: Fig. 2 :

Figure 5: F

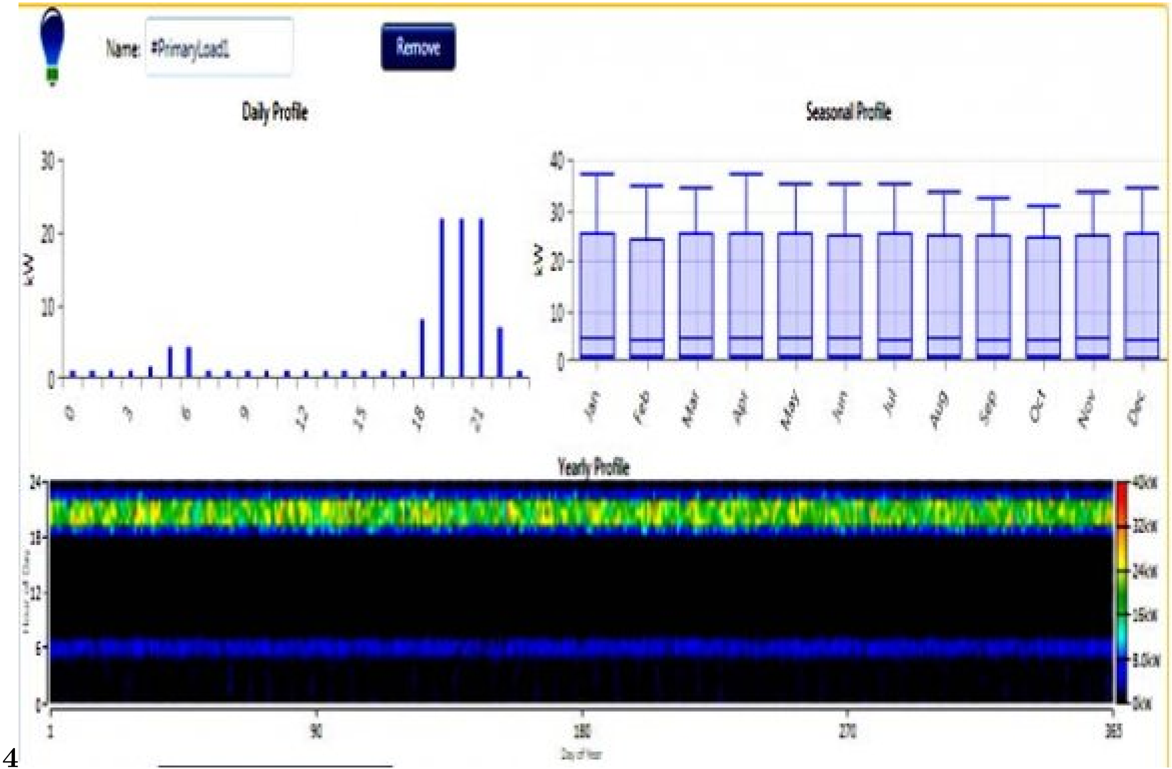

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Figure 6: Fig. 4 :

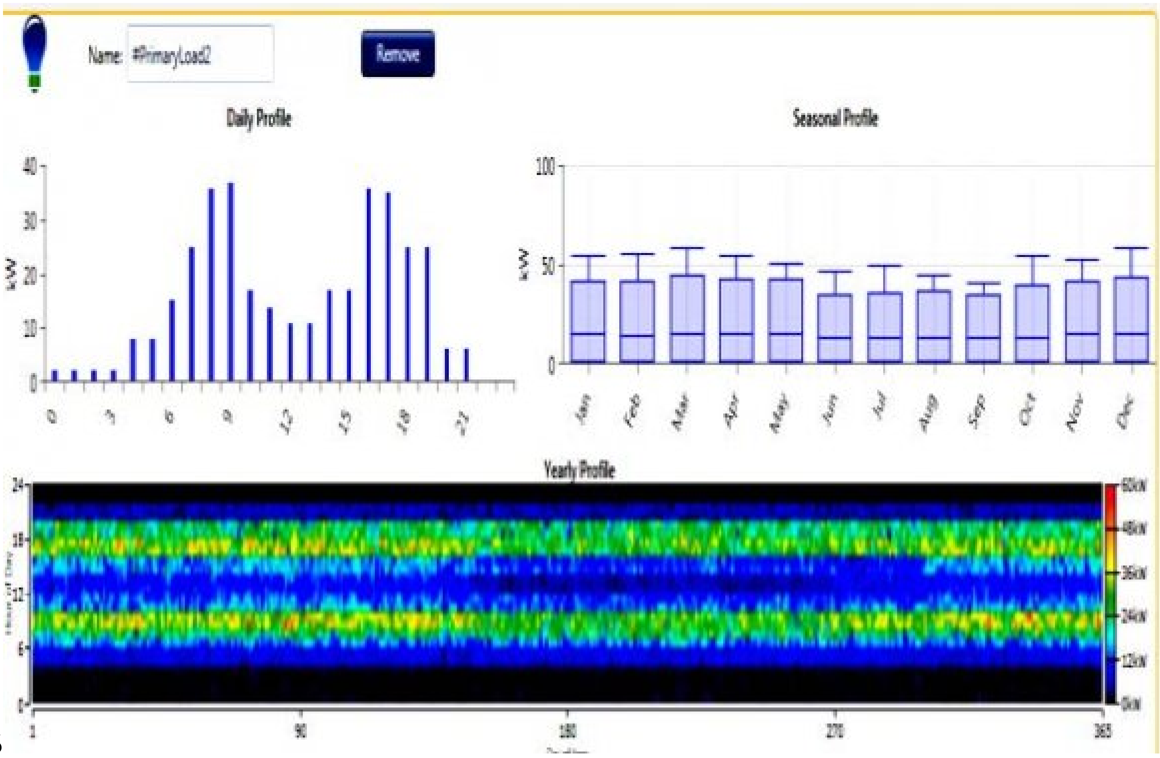

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Figure 7: Fig. 5 :

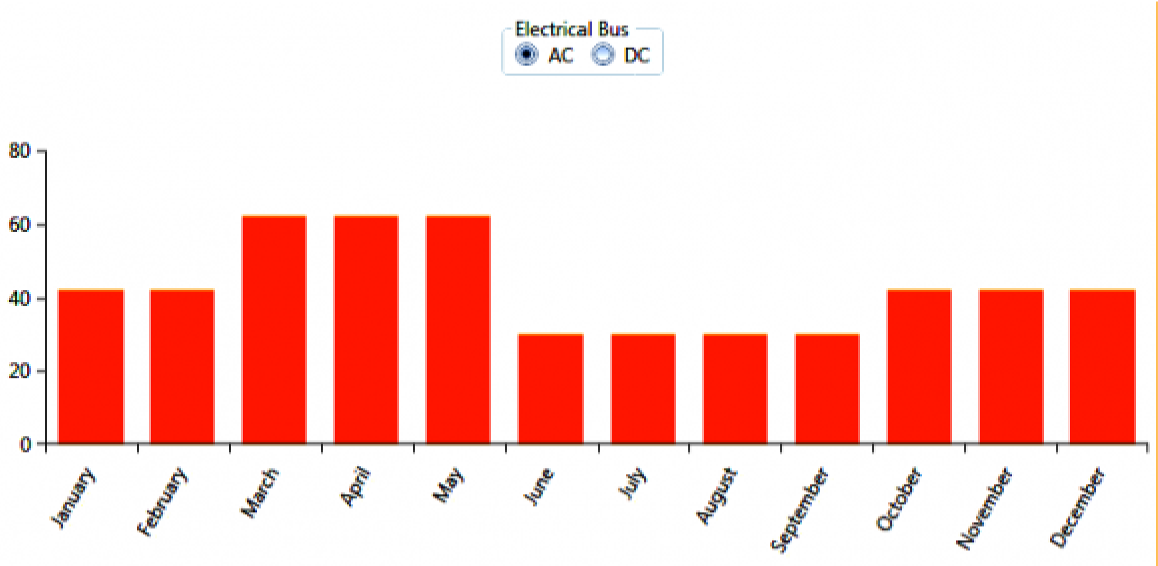

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Figure 8: Fig. 6 :

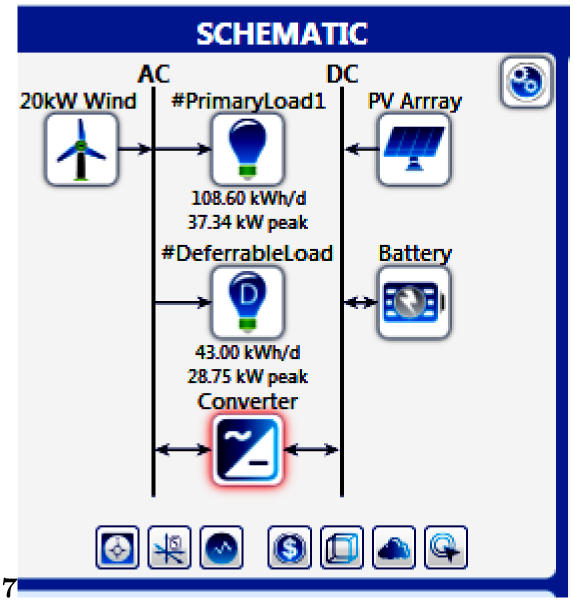

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Figure 9: Fig. 7 :F

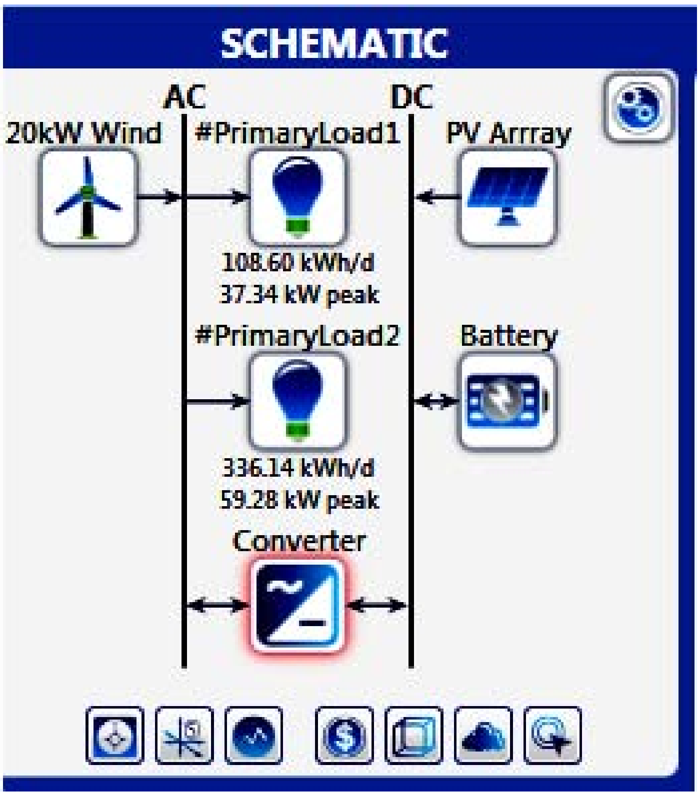

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Figure 10: Fig. 8 :Fig. 9 :Fig. 10 :F

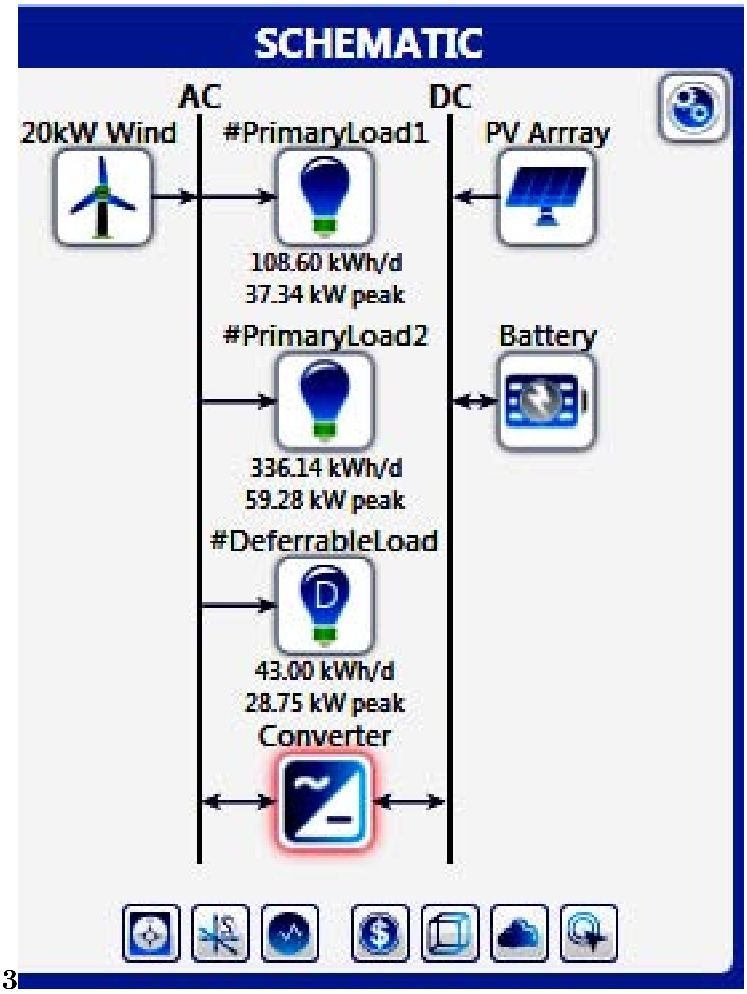

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Figure 11: Fig. 11 :Fig. 12 :Fig. 13 :F

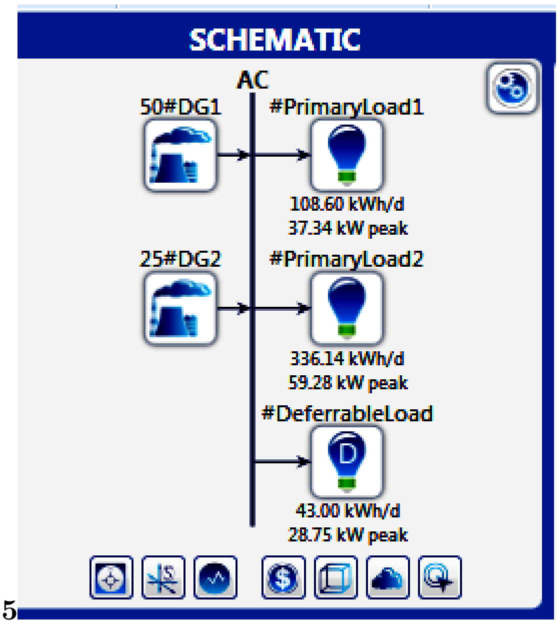

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Figure 12: Fig. 15 :

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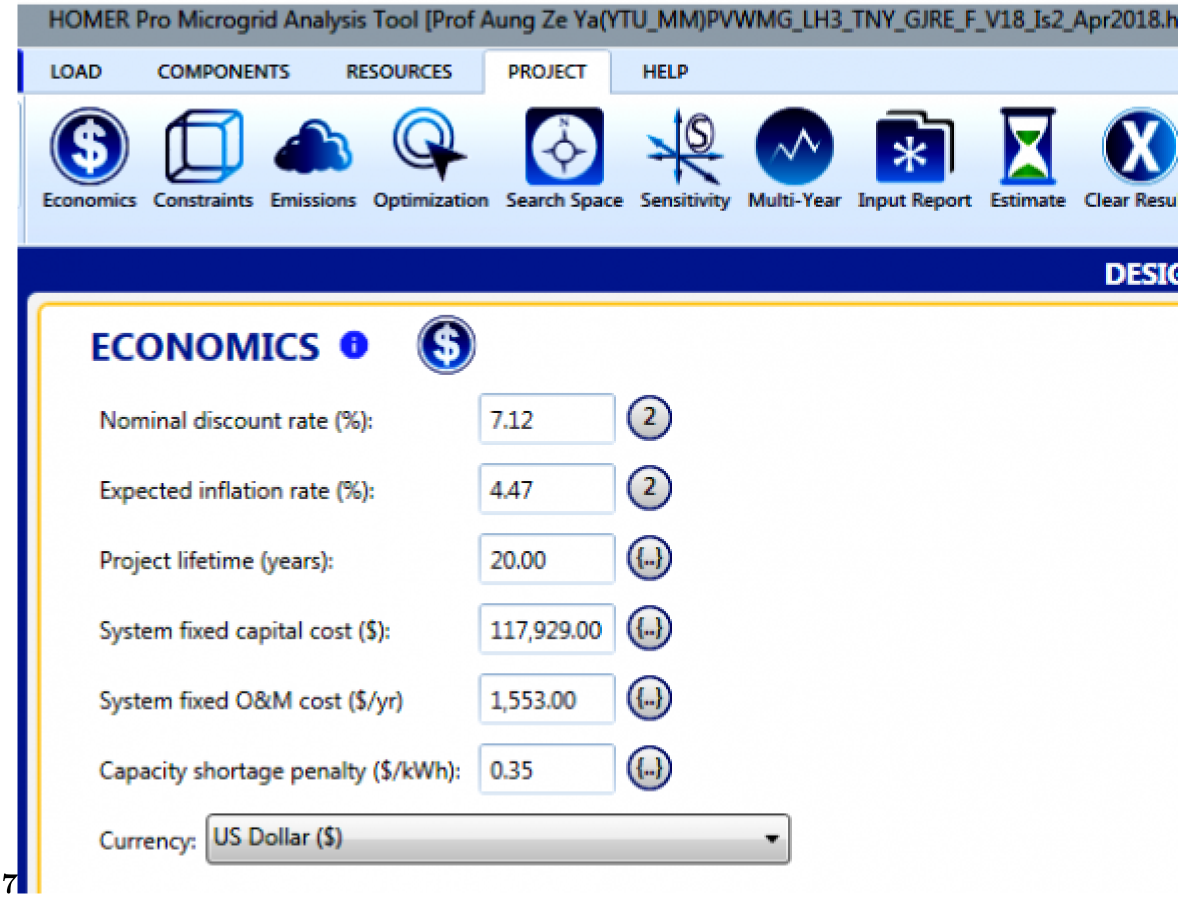

Figure 13: Fig. 17 :

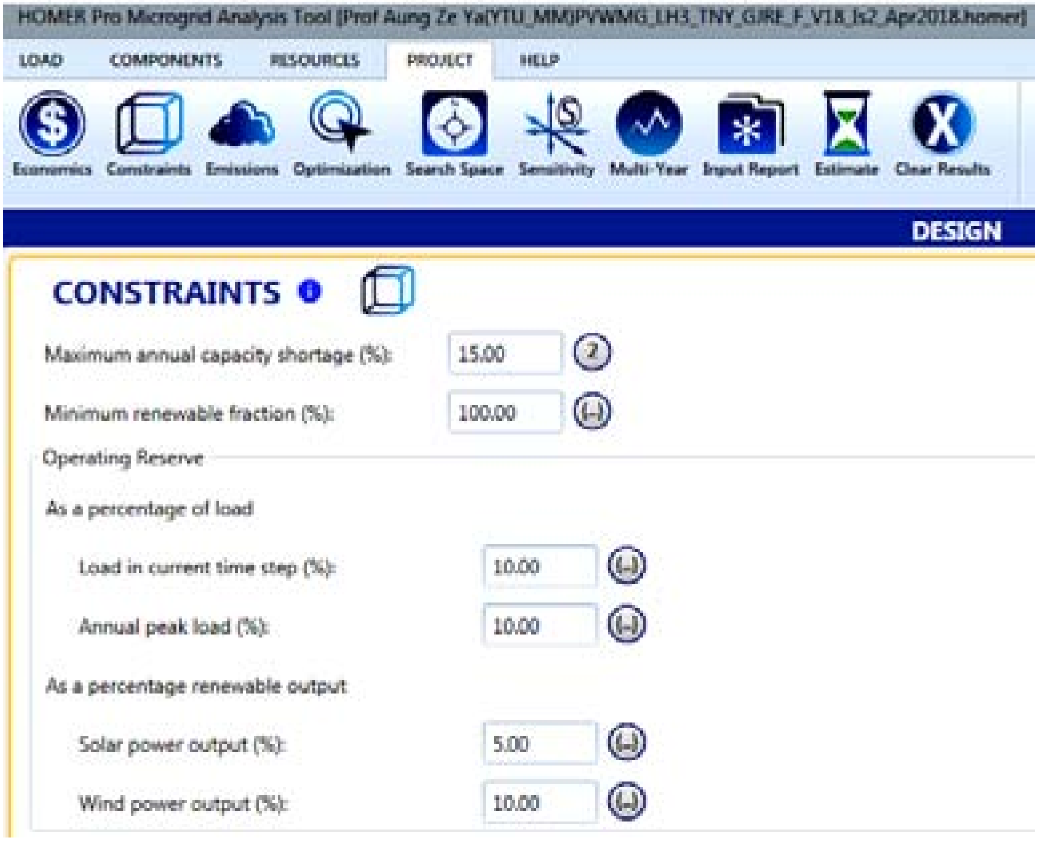

Figure 14: F

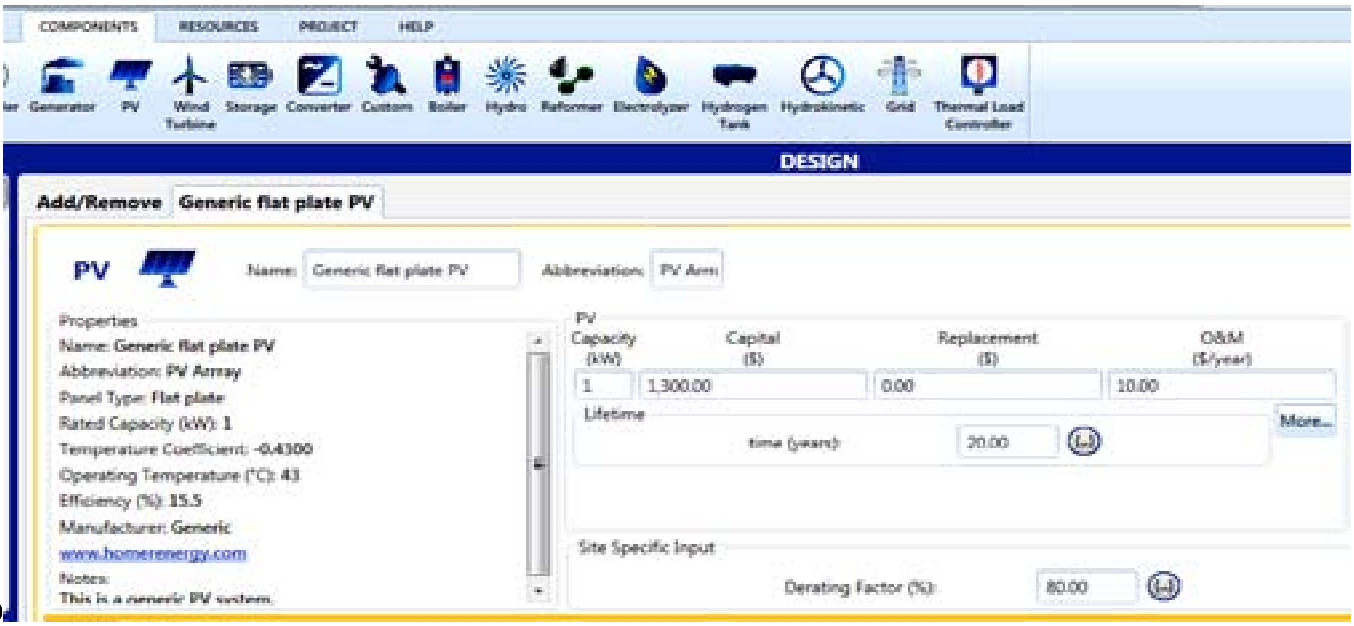

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Figure 15: Fig. 19 :

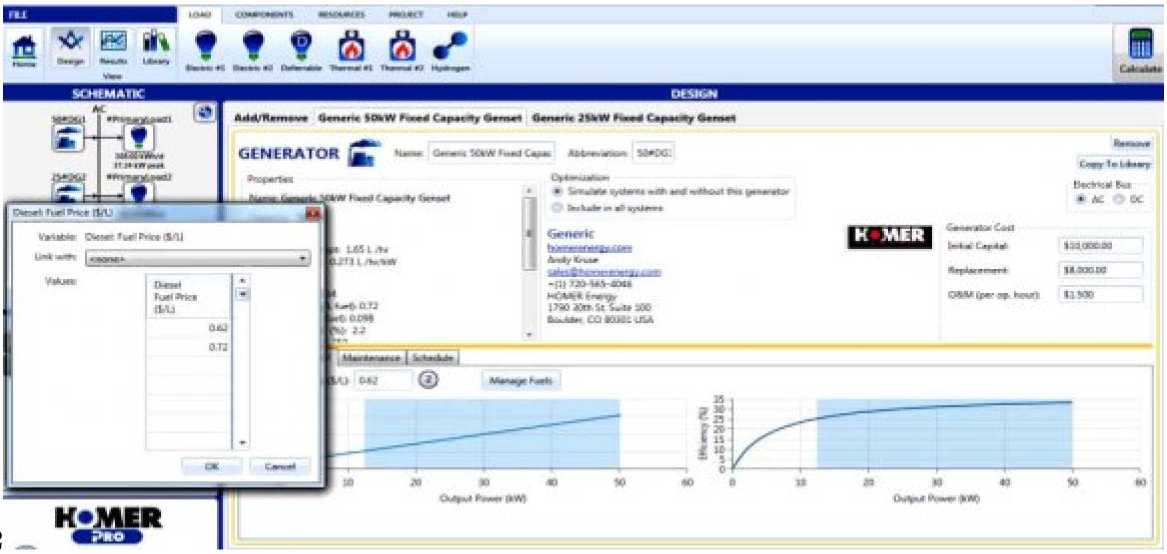
22 

Figure 16: Fig. 22 :F

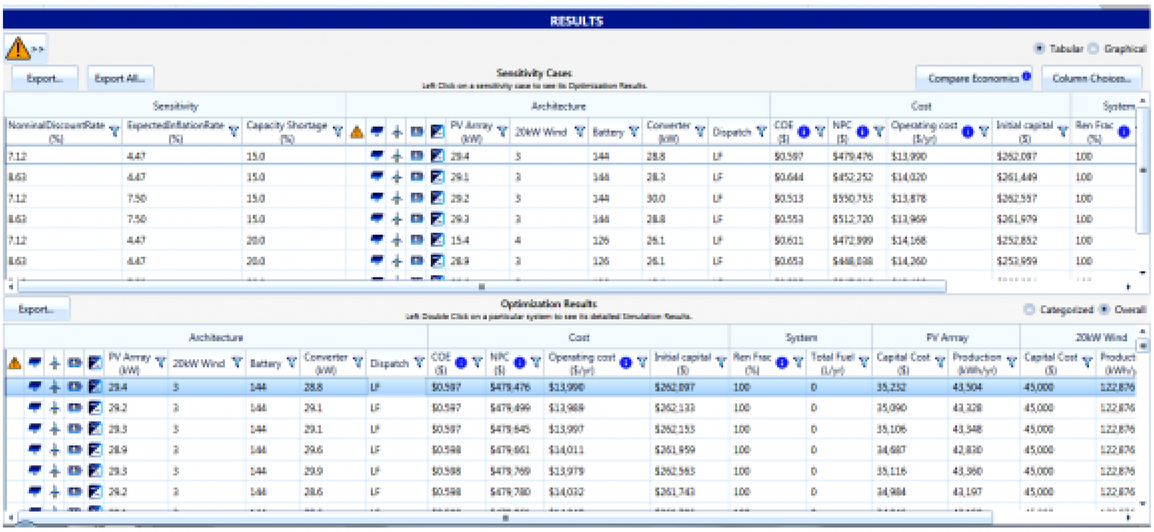
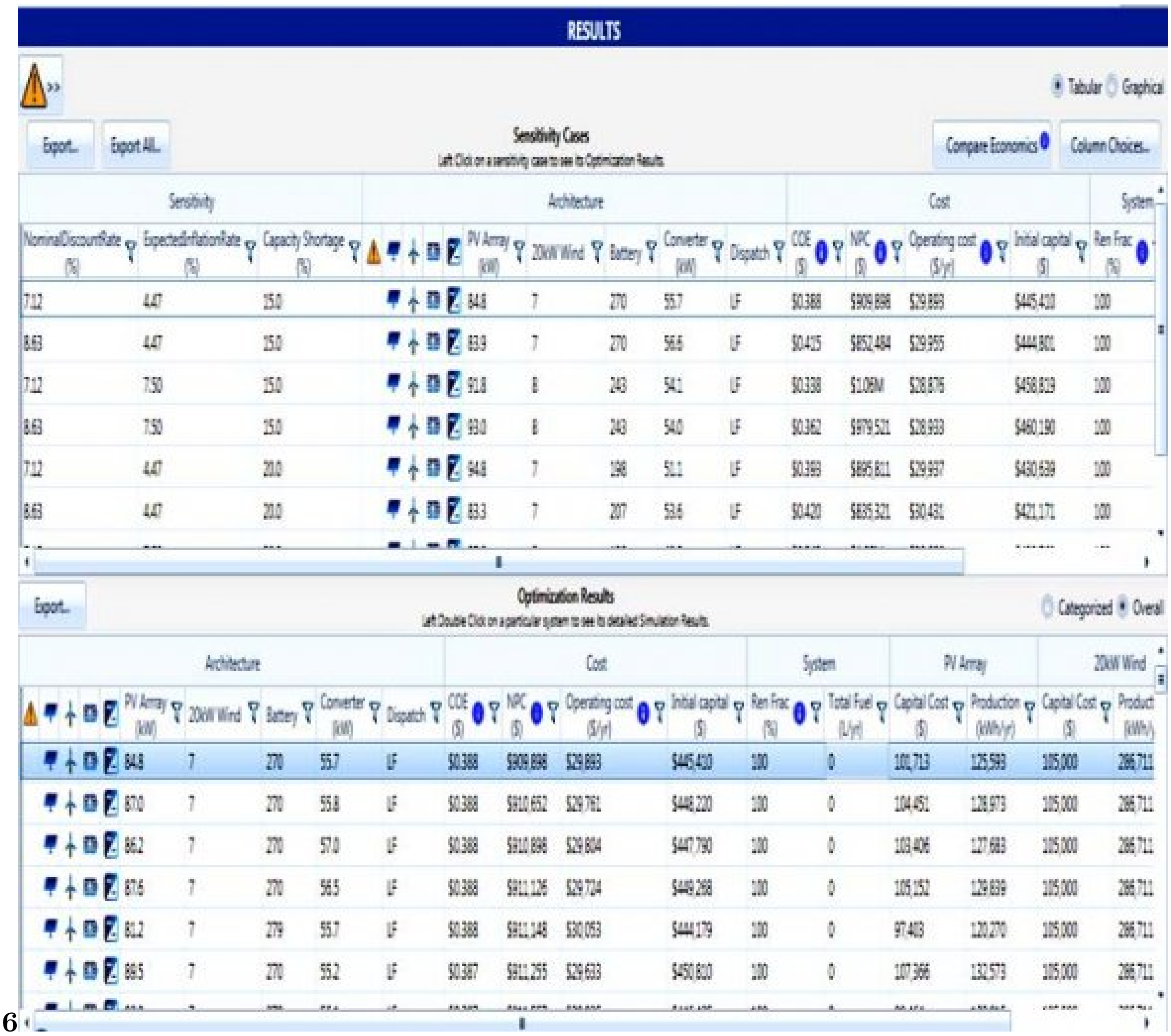
24 

Figure 17: Fig. 24 :



NominalDiscountRate (%)	ExpectedInflationRate (%)	Capacity Shortage (%)	PV Array (kW)	20kW Wind	Battery	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)
7.12	4.47	15.0	84.8	7	270	55.7	LF	$0.388	$909,898	$29,893	$445,410	100
8.63	4.47	15.0	83.9	7	270	56.6	LF	$0.425	$852,484	$29,955	$444,801	100
7.12	7.50	15.0	91.8	8	243	54.1	LF	$0.338	$1.06M	$28,876	$458,819	100
8.63	7.50	15.0	93.0	8	243	54.0	LF	$0.362	$979,521	$28,933	$460,190	100
7.12	4.47	20.0	94.8	7	198	51.1	LF	$0.393	$895,811	$29,937	$430,639	100
8.63	4.47	20.0	83.3	7	207	53.6	LF	$0.420	$835,321	$30,431	$421,171	100

PV Array (kW)	20kW Wind	Battery	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	PV Array Capital Cost ($)	PV Array Production (kWh/yr)	20kW Wind Capital Cost ($)	20kW Wind Product (kWh/)
84.8	7	270	55.7	LF	$0.388	$909,898	$29,893	$445,410	100	0	101,713	125,593	105,000	286,711
87.0	7	270	55.8	LF	$0.388	$910,652	$29,761	$448,220	100	0	104,451	128,973	105,000	286,711
86.2	7	270	57.0	LF	$0.388	$910,898	$29,804	$447,790	100	0	103,406	127,683	105,000	286,711
87.6	7	270	56.5	LF	$0.388	$911,126	$29,724	$449,268	100	0	105,152	129,839	105,000	286,711
81.2	7	279	55.7	LF	$0.388	$911,148	$30,053	$444,179	100	0	97,403	120,270	105,000	286,711
88.5	7	270	55.2	LF	$0.387	$911,255	$29,633	$450,810	100	0	107,366	132,573	105,000	286,711

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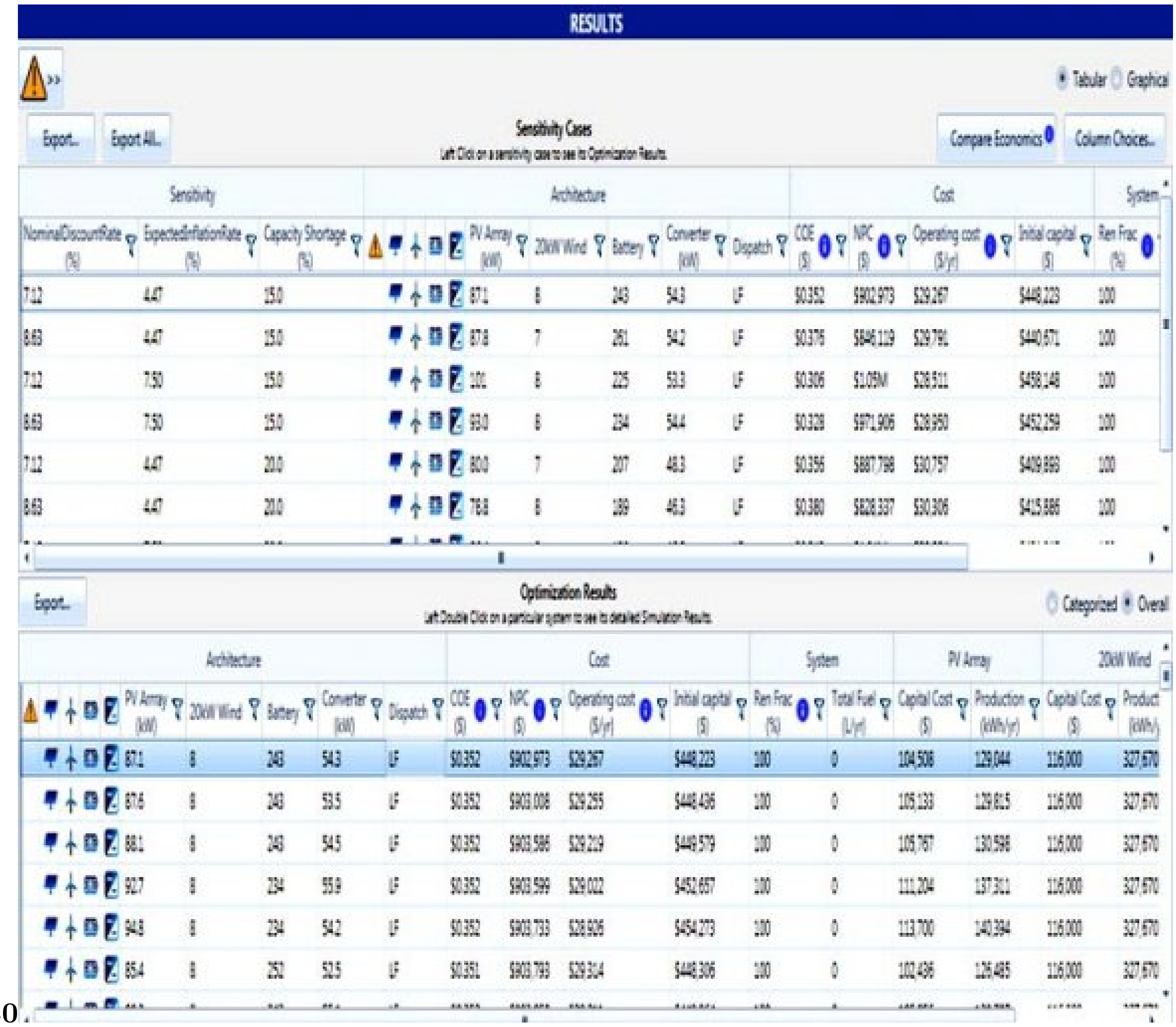
Figure 18: Fig. 25 :Fig. 26 :



Sensitivity			Architecture					Cost				System
NominalDiscountRate (%)	ExpectedInflationRate (%)	Capacity Shortage (%)	PV Array (kW)	20kW Wind	Battery	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)
7.12	4.47	15.0	87.1	8	243	54.3	LF	$0.352	$902,973	$29,267	$448,223	100
8.63	4.47	15.0	87.8	7	261	54.2	LF	$0.376	$846,119	$29,791	$440,671	100
7.12	7.50	15.0	101	8	225	53.3	LF	$0.306	$1.05M	$28,511	$458,148	100
8.63	7.50	15.0	93.0	8	234	54.4	LF	$0.328	$971,906	$28,950	$452,259	100
7.12	4.47	20.0	80.0	7	207	46.3	LF	$0.356	$887,798	$30,757	$409,693	100
8.63	4.47	20.0	78.8	8	189	46.3	LF	$0.380	$828,337	$30,306	$415,886	100

Architecture					Cost				System		PV Array		20kW Wind	
PV Array (kW)	20kW Wind	Battery	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Total Fuel (L/yr)	Capital Cost ($)	Production (kWh/yr)	Capital Cost ($)	Product (kWh/)
87.1	8	243	54.3	LF	$0.352	$902,973	$29,267	$448,223	100	0	104,508	129,044	116,000	327,670
87.6	8	243	53.5	LF	$0.352	$903,008	$29,255	$448,436	100	0	105,133	129,815	116,000	327,670
88.1	8	243	54.5	LF	$0.352	$903,586	$29,219	$449,579	100	0	105,767	130,598	116,000	327,670
92.7	8	234	55.9	LF	$0.352	$903,599	$29,022	$452,657	100	0	111,204	137,311	116,000	327,670
94.8	8	234	54.2	LF	$0.352	$903,733	$28,926	$454,273	100	0	113,700	140,394	116,000	327,670
85.4	8	252	52.5	LF	$0.351	$903,793	$29,314	$448,306	100	0	102,436	126,485	116,000	327,670

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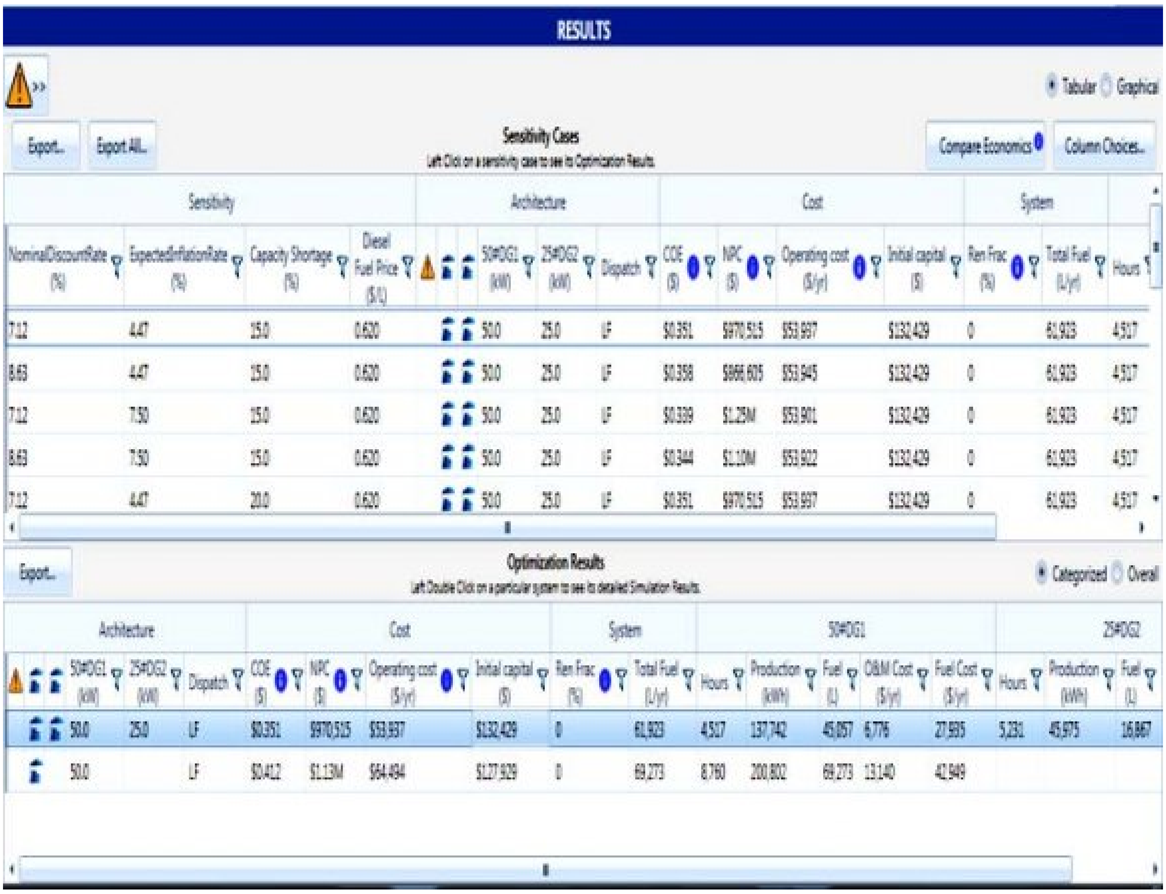
Figure 19: Fig. 30 :FF


RESULTS
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Sensitivity Cases
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Architecture
Cost
System
Optimization Results
Categorized
Overall

Figure 20:

validated as the fifth step. The principal work is the Techno-Economic Optimizations of different models performed in the well-proven tool, HOMER Pro (version 3.11.5). The final step is the selection of the Best Model.

The identified problems are:

1) Contribution to the Global Warming due to the GHG Emissions from the burning of the Diesel fuels and the fuelwood [15-18],
2) Deforestation and Climate Change from the application of the fuelwood for the cooking,
3) Degradation of the bio-diverse eco-systems in the Coastal Region,
4) Health problems from the burning of the Diesel fuels and the fuelwood [20-22],
5) Easy to be fire hazards from the applications of the Diesel Generators and the firewood,
6) Insufficient and the limited supply from the existing SHS and the Diesel Generators, and
7) Environmental (Negative) impacts from the usages of the Fluorescent Lamps [19-21].

Hierarchical Methodology

Selection of the Best Model

Simulation in HOMER Pro

Validation of Input Parameters

Selection of Technology and Component

Evaluations of Load Profiles

Selection of Renewables

Site Survey

II. ZERO-EMISSION ENERGY (STANDALONE PV-WIND-BATTERY HYBRID) MODEL IN HOMER PRO

Fig. 3: Project Location (Village Lel Hpet)

[Note: a)]

Figure 21: Project Location in Tanintharyi Coast Fig. 3 mentions the project location in the map- box of HOMER Pro. The village Lel Hpet in Tanintharyi Coast placed according to its geographical coordinates

1

Load Type	Description	Power (kW)	Amount
PL2	Carpentry Workshop	1000	8
	Cold Storage	140	20
DL2	Water Pumping	1500	15

Figure 22: Table 1 :

2

Group	Primary Load 1 (kilowatt, kW)	Primary Load 2 (kW)	Small Deferrable Loads (kilowatt hour, kWh)
Low	1.320	22.5	1.305
Medium	13.833	192.5	13.020
High	11.600	60	4.350

Figure 23: Table 2 :

4

Model	Design	Capacity	Annual Production/ Throughput (kWh/yr)	Cost of Energy ($)	Net Present Cost ($)	Operating Cost ($/ yr)	Initial Capital ($)	Diesel Fuel (L/yr)	($/L)	($/yr)
M1	PV	29.4 kW	43504	0.597	479476	13990	262097	-	-	-
	Wind	60 kW	122876							
	Battery	144 kWh	19037							
	Converter	28.8 kW	-							
M2	PV	84.8 kW	125593	0.388	909898	29893	448220	-	-	-
	Wind	140 kW	286711							
	Battery	270 kWh	38361							
	Converter	55.7 kW	-							
M3	PV	87.1 kW	129044	0.352	902973	29267	448223	-	-	-
	Wind	160 kW	327670							
	Battery	243 kWh	34360							
	Converter	54.3 kW	-							
M4	DG1	50	137742	0.351	970515	53937	132429	45057	0.62	27935
									0.72	32441
	DG2	25	45975					16867	0.62	10457
									0.72	12144

Figure 24: Table 4 :

.1 Acknowledgements

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