Solutions and Energy Management Optimization for Hybrid Renewable Energy System at Babylon University, Engineering College, Iraq

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***Abstract*—The design of hybrid energy systems requires sustainable resources and main components such as energy management. The Iraqi government has advised educational facilities, such as universities, to use renewable energy resources to reduce electricity consumption because Iraqi energy supply systems depend mainly on fossil fuel. The loads in Iraq have expanded during the last few years while generation stations and networks have remained the same. Therefore, hybrid optimization of multiple energy resource software has been used to investigate possible solutions that can be applied to generate the required power for Babylon University, Engineering College. Eight on-grid cases were examined for producing the required power. Grid-WT-BT(Case4) which has the lowest cost of energy (COE) and net present cost (NPC) value with 51.8% renewable energy penetration was found to be the most feasible. The results showed that the Grid (1,964,518 kwh/y), NWT (50), NBT (4), Nconv (2), COE (0.0677 US$/kwh), NPC (US$3.19 million), and IC (US$ 853,031). Moreover, the energy requirements of AC primary load in this college can be satisfied by using this system.**

***Keywords*—Economic Feasibility; HOMER Analysis; Hybrid System; Optimal Solution; Renewable Energy Resource.**

I. INTRODUCTION

Many developed countries have adopted modern techniques to increase the use of renewable energy systems and resources; thus, reducing greenhouse gas emissions and fossil fuel depletion [1-2]. In this regard, the Iraqi government encourages companies to develop renewable alternative energy systems [3]. This approach plays an important role in reducing the high dependency on fossil fuels for electricity generation [4-5]. Education and research organizations have become the first institutions to install renewable energy facilities in their buildings. However, studies about the possibility of using renewable energy resources in Iraq are limited. The required energy generation is one of the main social issues in Iraqi universities. As highlighted by the Iraqi Ministry of Electricity, the energy needs of educational organizations have rapidly increased during the last few years because of an increase in the number of Iraqi universities. The energy supply of Iraqi universities is currently divided between national grid electricity (approximately 60%) and diesel generators (approximately 40%). The electricity consumption of Iraqi universities will continue to increase in the future because they are operated using electricity-oriented products [6-13]. Thus, most universities are looking forward to reduce electricity bills in their educational services. This phenomenon indicates that establishing sustainable renewable energy facilities plays a main role in increasing competitiveness among universities. This work presents several techniques for satisfying the electricity demand of Babylon University, Engineering College. This college often uses the electricity grid and diesel generators. After implementing new policies, the college of engineering attempted to effectively design a renewable power generation system to be used in place of the present grid-electricity system. The hybrid optimization of multiple energy resource (HOMER) model is applied in this work [14-19]. The structure of a possible renewable energy system is discovered by this model. The design depends mainly on two important parameters, namely, the cost of energy (COE) and the net present cost (NPC).

II. STATUS OF BABYLON UNIVERSITY, ENGINEERING COLLEGE

A. Campus Location

The campus of the engineering college is located at (32°23.6'N, 44°23.9'E), which is 100 km south of the capital of Iraq. The campus comprises six buildings (mechanical, chemical, civil, and electrical departments; deanship; and factory), a library, and two facility buildings, as shown in Figure 1.

B. Campus Load Information

At present, the main electricity resources of the engineering college are electricity grid and diesel generators. According to the given data, the value of mean energy demand per year is 8,409.86 kwh/d, whereas the peak energy demand is 2,247.9 kw, as shown in Figure 2.

Figure 1: Geographical location of Babylon University

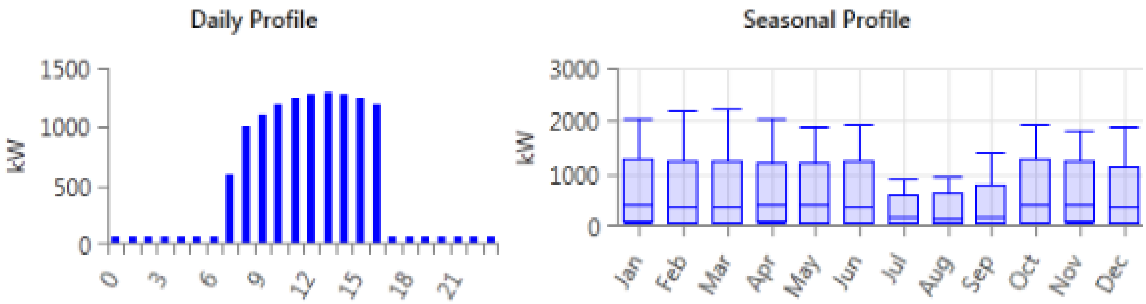


Figure 2: Load profile

Table 1
Energy Consumption of Babylon University, Engineering College

N	Load Equipment	Quantity	Power (Watts)	Time of Use (H)	Energy Required (W/H)
1	Lamps	250	20	7	35,000
2	Lamps(out)	200	20	12	48,000
3	Air conditioning 2 ton	155	2,000	7	2,170,000
4	Air conditioning 3 ton	178	3,000	7	3,738,000
5	Air conditioning 5 ton	31	5,000	7	1,085,000
6	Air cooler	9	400	7	25,200
7	Ceiling fan	991	250	7	1,734,250
8	Vertical fan	189	300	7	396,900
9	Air puller	106	1,000	7	742,000
10	Desktop computer	341	200	7	477,400
11	Laptop computer	222	200	7	310,800
12	Scientific Calculator (12 digits)	15	200	7	21,000
13	Scanner machine	45	200	2	18,000
14	Copy machine	47	500	2	47,000
15	Laser Printer	191	200	2	76,400
16	Water cooler	28	300	7	58,800
17	water pump	108	800	7	604,800
18	Water filter system	29	100	7	20,300
19	Water heater	6	3,000	7	126,000
20	Internet system	7	200	7	9,800
21	TV set	115	200	7	161,000
22	Refrigerator	164	300	20	984,000
	Total AC Average daily load				12,889.65 kwh/d

C. Solar, Wind Energy Potential at Babylon University, Engineering College

The information of solar radiation, temperature and wind speed was collected from the NASA surface meteorology as well as solar energy database 2019. The annual solar radiation is 5.16 kWh/m2/d [20]. Figure 3 shows the average solar energy baseline data per month. The annual temperature was determined to be 24.44 ºC, as shown in Figure 4 [20]. The value of annual wind speed is 5.46 m/s [20]. Figure 5 shows the baseline data for the wind resource.

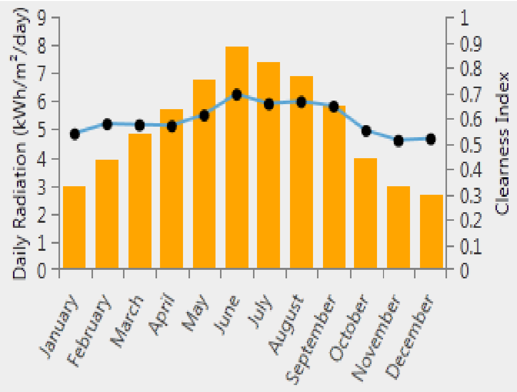


Figure 3: The annual solar radiation

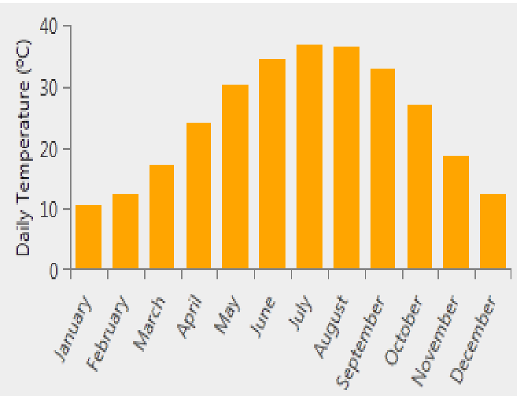


Figure 4: The annual temperature

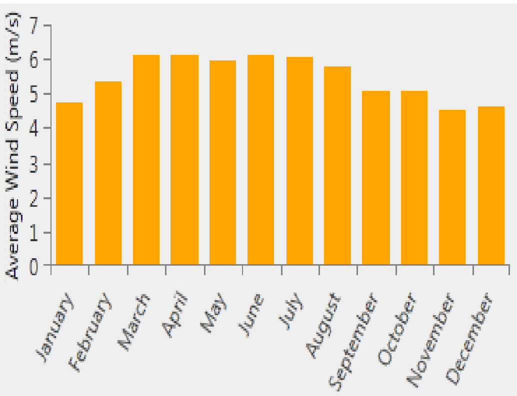


Figure 5: The annual wind speed

III. Key Parameters For Economic Analysis

A. Cost of Energy (COE) and Net Present Cost (NPC)

In general, COE is defined as the average cost per kwh of electrical energy generated by the system [21]. The total cost per year represents the summation of all system costs with its components in addition to other subjective costs annually. COE represents a key simulation output because all components of the suggested systems are calculated on the basis of their COE. The HOMER simulations provide the whole NPC, which represents the major economic element [22, 23]. The lifecycle cost involves the full installation and the maintaining cost of the system. Moreover, the project lifetime during this study is 20 years.

B. Diesel Price

Diesel price represents the major element that should be calculated for diesel generator during system design. According to the Iraqi Ministry of Oil, the diesel price for simulation is considered at 0.31 $/L [24].

IV. Various Scenarios Of Renewable Power Generation Systems

Several scenarios have been analyzed, depending on the included components such as PV, WT, DG, BT, converters, and grid, as shown in Table 3. The reliability and feasibility of the system, which are measured by HOMER simulations, represents the scale between the scenarios. The proposed parameters of this study are the installation costs of $1,250, the annual O&M costs of $10, and the replacement costs of $1,250. In addition, the lifetime of PV panel is 25 years. The size of solar energy system is 1 kw, as shown in Table 2. The wind turbine cost, replacement cost, as well as annual O&M cost are $17,000, $17,000, $120 respectively. Additionally, the turbine lifetime is 20 years, as shown in Table 2. It is difficult to select the parameters of the generator for simulation because there are many diesel generators. Based on previous studies that had been reviewed to find the detailed parameters of diesel generators, the parameters of the generator that have been selected are the capital cost of $12,500, the cost of replacement of $12,500, the O&M cost of 0.25 $/hour, as well as the 15,000 hours lifetime. The power of the generator is 100 kw, as shown in Table 2. A power electronic converter was used to convert the power between AC and DC components. The data of 1kw system is the installation cost of $500, annual O&M cost of $10, cost of replacement of $500, and converter's lifetime of 15 years, as shown in Table 2. Generally, the price of batteries, which is very important in renewable generation systems is high. In this study, the battery cost, replacement cost and annual O&M cost are $500, $500, and $10 respectively, as shown in Table 2.

Table 2
The Suggested Data of the Project

N	Capital Cost	Replace Cost	O & M	Lifetime	Power	Type
1	$1,250	$1,250	$10/y	25 years	1 kw	PV
2	$17,000	$17,000	$120/y	20 years	10 kw	WT
3	$500	$500	$10/y	10 years	1 kwh	BT
4	$500	$500	$10/y	15 years	1 kw	Conv.
5	$12,500	$12,500	$0.25/h	15,000 hours	100 kw	DG

V. The Scenarios Considered For Babylon University, Engineering College

In this section, some scenarios have been taken into account for the purpose of supplying the electricity demand of Babylon University, engineering college with various energy sources. For each scenario, the overall COE, NPC, and IC were determined. Rent or price, tax and other expenses were excluded from the virtual simulation. This study developed different scenarios for this university by integrating different parts/devices, such as PVs, WTs, DGs, BTs, converters and grid to ensure that the simulations are reliable and feasible. Ultimately, the aim of this analysis is to evaluate technically and economically, the viability of eight different configurations, all are potential configurations to obtain the optimal combination for electrical power generation. As shown in Table 3, the simulation was carried out for the scenarios:

Table 3
The Scenarios Used

System Type	Scenarios	Grid	PV	WT	DG	BT	Converter
On-grid	1	✓	×	×	×	×	×
On-grid	2	✓	×	×	✓	×	×
On-grid	3	✓	✓	×	×	✓	✓
On-grid	4	✓	×	✓	×	✓	✓
On-grid	5	✓	✓	✓	×	✓	✓
On-grid	6	✓	✓	×	✓	✓	✓
On-grid	7	✓	×	✓	✓	✓	✓
On-grid	8	✓	✓	✓	✓	✓	✓

A. Scenario 1 (On-Grid)

The designed system with only national grid is shown in Figure 6, and their simulation results are shown in Figure 7.

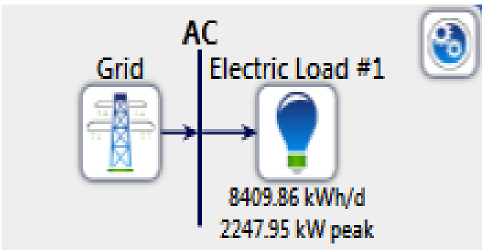


Figure 6: System design for scenario 1

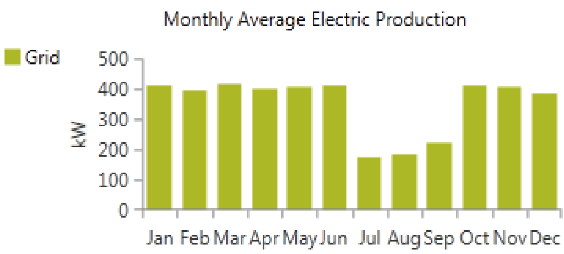


Figure 7: Simulation results for scenario 1

B. Scenario 2 (On-Grid)

The designed system with national grid, and diesel generators is shown in Figure 8, and their simulation results are shown in Figure 9.

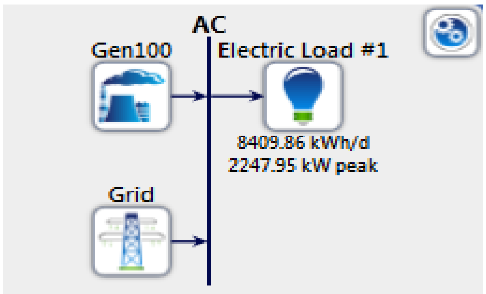


Figure 8: System design for scenario 2

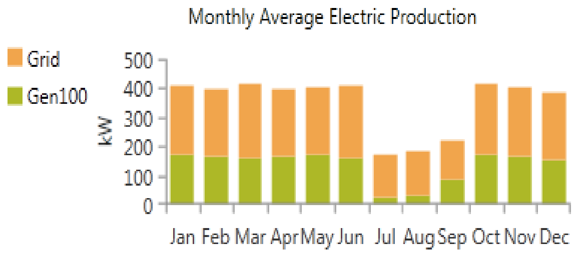


Figure 9: Simulation results for scenario 2

C. Scenario 3 (On-Grid)

The designed system with national grid, PV, BT, and converter is shown in Figure 10, and their simulation results are shown in Figure 11.

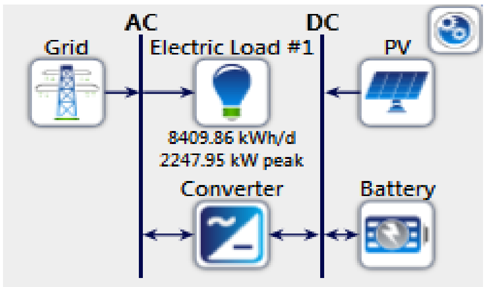


Figure 10: System design for scenario 3

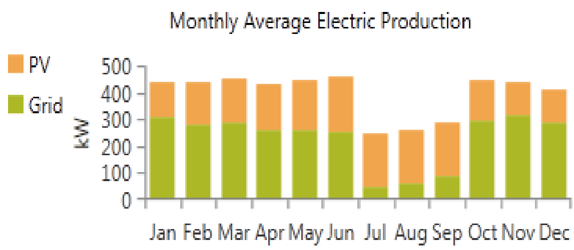


Figure 11: Simulation results for scenario 3

D. Scenario 4 (On-Grid)

The designed system with national grid, WT, BT, and converter is shown in Figure 12, and their simulation results are shown in Figure 13.

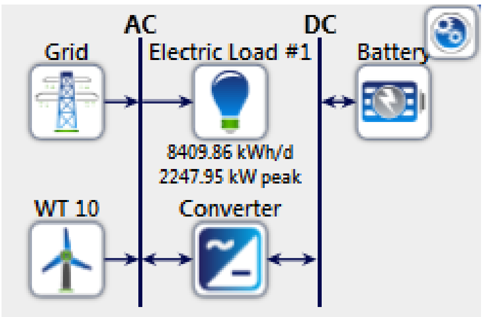


Figure 12: System design for scenario 4

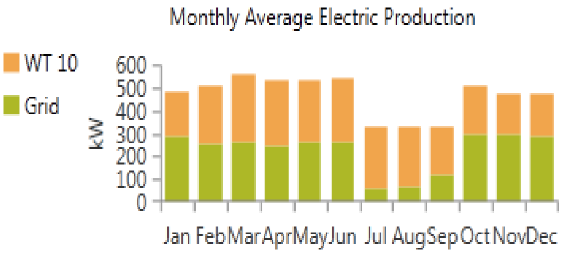


Figure 13: Simulation results for scenario 4

E. Scenario 5 (On-Grid)

The designed system with national grid, PV, WT, BT, and converter is shown in Figure 14, and their simulation results are shown in Figure 15.

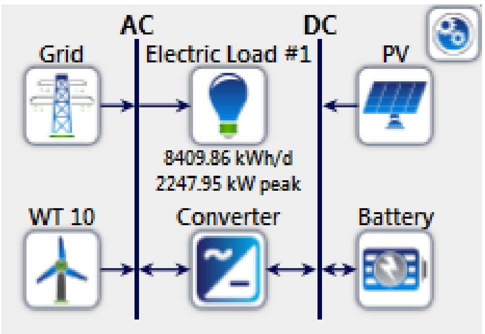


Figure 14: System design for scenario 5

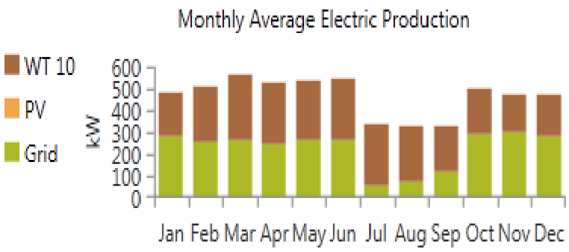


Figure 15: Simulation results for scenario 5

F. Scenario 6 (On-Grid)

The designed system with national grid, PV, DG, BT, and converter is shown in Figure 16, and their simulation results are shown in Figure 17.

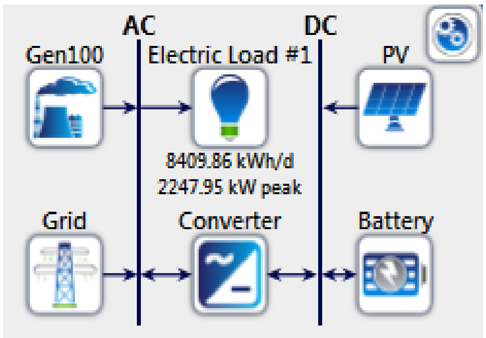


Figure 16: System design for scenario 6

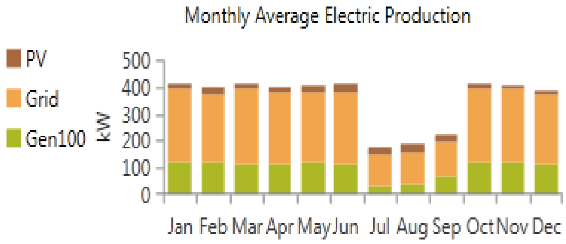


Figure 17: Simulation results for scenario 6

G. Scenario 7 (On-Grid)

The designed system with national grid, WT, DG, BT, and converter is shown in Figure 18, and their simulation results are shown in Figure 19.

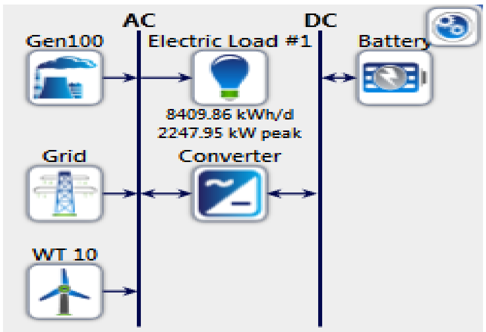


Figure 18: System design for scenario 7

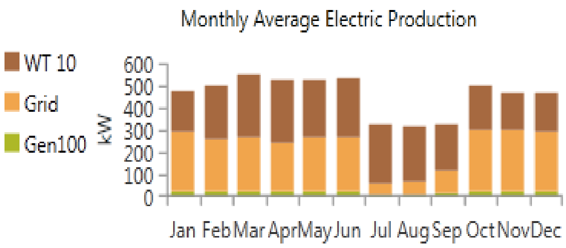


Figure 19: Simulation results for scenario 7

H. Scenario 8 (On-Grid)

The designed system with national grid, PV, WT, DG, BT, and converter as shown in Figure 20, and their simulation results are shown in Figure 21.

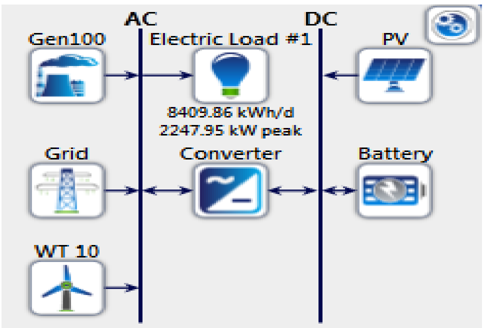


Figure 20: System design for scenario 8

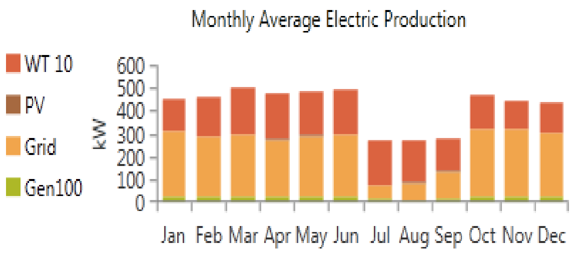


Figure 21: Simulation results for scenario 8

VI. Discussion

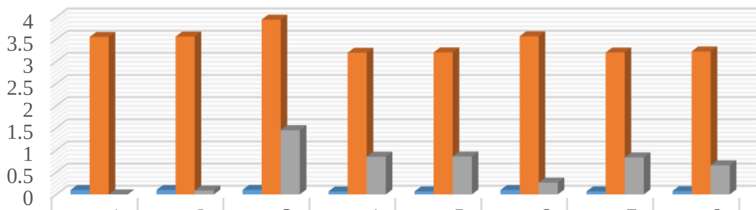
Diesel generators, wind turbine, solar panels, and grids were used as bases for designing eight renewable generation systems. The software program HOMER, which can select the most convenient design from an economic perspective after performing a parametric analysis of system configurations, was used to produce a dynamic model of the plant. The three main economic indicators were the COE, NPC and IC. According to the cost analysis results, a combination of a (grid-WT) hybrid system (case 4) with 51.8% and grid power contribution with 48.2% is the most economical system for the University of Babylon, Engineering College, with the COE of $ 0.0677/kwh, IC of $853,031, and NPC of $3,199,528, as shown in Table 4. The second scenario (grid-DG) is not acceptable because diesel generators do not relate to renewable energy resources.

VII. Conclusion

The main goal of this work was to explore the renewable power generation systems of Babylon University, Engineering College in Iraq. Different on-grid configurations were systematically investigated in this work. The contribution of wind energy is higher than that of solar PV energy for the proposed hybrid power systems. When the capital cost is the only criterion, the grid-based system will be the best option, followed by the grid-DG-based system. If the campus electricity must be supplied by the hybrid system, it should start to maintain the current system (grid-DG), while establishing a renewable power generation system is important. After installing renewable power generation facilities, the use of the diesel generator system should be reduced gradually. The installation of hybrid renewable-based configurations depends mainly on the role of the Iraqi government. In addition, recent legislation that supports the application of these units involves merely tax reductions and exemptions. In fact, this support is not enough to satisfy the possibility of using these systems. If the incentives and supporting policies are provided by the government, then the optimal size of the components and configurations that are suggested in this study can be applied to generate the required energy in the most economical method.

Table 4
Detailed Simulation Results

N	NPV	NWT	NDG	NBT	NConv	Grid (kwh)	COE (US$/kwh)	NPC (US$)	IC (US$)
1	-	-	-	-	-	3,069,600	0.1000	3,554,682	0
2	-	-	700	-	-	1,892,545	0.1003	3,563,930	87,500
3	894	-	-	67	587	1,995,072	0.1021	3,944,500	1.45M
4	-	50	-	4	2.06	1,964,518	0.0677	3,199,528	853,031
5	1.2	50	-	12	0.103	1,964,230	0.0679	3,206,504	857,546
6	124	-	500	3	97.9	1,995,247	0.1004	3,570,350	268,545
7	-	48	100	4	12.3	1,799,658	0.0688	3,204,664	836,654
8	21.9	35	100	36	8.78	1,972,559	0.0757	3,227,204	657,267



	case 1	case 2	case 3	case 4	case 5	case 6	case 7	case 8
COE ($/kwh)	0.1	0.1003	0.1021	0.0677	0.0679	0.1004	0.0688	0.0757
NPC (M$)	3.5546	3.5639	3.9445	3.1995	3.2065	3.5703	3.2046	3.2272
Initial capital (M$)	0	0.0875	1.45	0.853	0.8575	0.2685	0.8366	0.6572

Figure 22: System costs associated with each case

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