ISSN 2347-4289

Why A Green-Based Generation Expansion Plan For Kenya? A Comparative Analysis

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ABSTRACT: The main concern in the global generation sector was the huge CO_2 emissions from the conventional power generation. In Kenya, the sector prepares 20 year rolling least cost power development plan (LCPDP) for expanding the power system to meet the current and future power demands. The 2011-2031 LCPDP generation plan proposed a system expansion that would result in a 33% fossil fuel power generation posing a huge CO_2 emission dilemma. Consequently, a green least-cost generation expansion plan (GLCGEP) was derived from the Kenya's numerous renewable energy resources. However, the question of whether or not the plan was preferable over the LCPDP and the way forward for the Kenya's generation sector remained unanswered. This study sought the answer to this question through a comparative study of the two generation expansion plans. The findings of the study established that the GLCGEP would have a relatively modest reserve margin averaged at 25% and more than US$2.16 billion net revenues by the end of the 2011-31 planning period. Nothwitstanding, the envisaged energy system showed ample social-economic benefits for green growth. Therefore the research recommended future studies on modelling grid reliability and stability with high penetration of variable renewable energy sources.

Keywords : generation expansion planning; capacity; reserve margins, carbon credits, system's cost, net present value.

1.0 INTRODUCTION

The world power generation sector is projected to undergo unprecedented demand growth from 17,408 TWh in 2004 to 33,750 TWh in 2030 at an average annual growth rate of 2.6%. To meet this demand, the sector will built 5,087GW of which over 75% will come from oil, coal and gas power plants. Consequently, the carbon-intensive plants are expected to rise the CO2 emissions from 9600-16400Mt at an annual growth rate of 2%. The rapidly increasing global emission is the major cause of global climate change [1]. Consequently, the global generation sector is faced with enormous pressure to lead the way in climate change mitigation strategies. Thus generation companies (GENCOs) in many countries in the world are currently planning towards environmentally-friendly generation investments [1], [2]. The most popular energy policy measure towards this course is the use of Renewable energy (RE) as suitable clean energy option to the conventional carbon intensive plants [3], [4]. Subsequently, more integration of RE in the power system's least-cost generation expansion planning (GEP) is rapidly gaining extraordinary consideration as a sustainable option to security of power and CO_2 emission reduction [5], [6]. The system integration also presents a significant potential for carbon credits as revenues in the generation sector from the carbon market [7], [8], [9]. Furthermore, other fringe benefits such as health benefits, green jobs and foreign exchange savings prevail for sustainable development [10], [11]. In Kenya, the generation sector prepares 20 year rolling least cost power development plan (LCPDP) at the energy regulatory commission (ERC) for expanding the power system to meet the current and future power demands. The 2011-2031 LCPDP under the focus of this study had projected a hydropower and heavy fuel oil (HFO) dominated power generation [12] that posed serious challenges. The hydros were vulnerable to acute energy shortfalls due to the frequent droughts. On the other hand, the HFO and the planned conventional coal plants posed the CO_2 emissions dilemma [13], [14]. These were crucial issues for urgent attention by energy planners. Consequently, a study by [15] on green-based GEP using the Wien Automatic software package (WASP) IV was carried to derive a green least-cost generation expansion plan (GLCGEP). Although a 78% capacity expansion plan was achieved from the portfolio of enormous under-exploited RE resources in Kenya, the question of whether or not the plan was preferable over the LCPDP and the way forward for the generation sector remained unanswered. This study sought the answer to this question through a comparative study of the two generation expansion plans. This paper is divided into six sections. The section two gives an overview of the two generation expansion plans. Section three presents the methodology. Section four presents the results. Section five gives the discussion and lastly six present the conclusion and recommendations for future research.

2.0 OVERVIEW OF THE GENERATION EXPANSION PLANS

2.1 THE 2011-31 LEAST COST POWER DEVELOPMENT PLAN (LCPCP)

The least cost generation expansion plan in the LCPDP was derived to meet the projected energy demand over the 2011-2031 planning period. Table 1 illustrates the generation capacity expansion plan by fuel type for the LCPDP. The hydropower dominated capacity in the base year was varied by capaccity additions to geothermal dominated by 2031. Thus, by 2031, 26% of the planned capacity was expected to come from geothermal, 19% from nuclear (starting in 2022) and 13% from coal (starting in 2015). Furthermore, others were 11% from natural GT (starting in 2020), 9% each from HFO, wind & hydropower imports from Ethiopia and 5% from local hydropower.

ISSN 2347-4289

Table 1: LCPDP Capacity (MW)

Year	Hydropower	Nudear	HFO	Import	Baggsse	GT-KERO	GT-NGA	Geothemal	Coal	Wind	System's Capacity	Peak Load	Reserve Margin
2010	741	-	333	-	26	60	-	198	-	5	1,363	1,227	11
2011	761	-	453	-	26	60	-	198	-	5	1503	1302	15
2012	782	-	453	-	26	60	-	206	-	5	1,532	1,520	0.7
2013	782	-	705	-	26	60	-	241	-	186	2,000	1,765	13.2
2014	814	-	705	200	26	-	-	608	-	535	2,888	2,064	39.9
2015	839	-	705	200	26	-	-	843	20	535	3,168	2,511	26.1
2016	839	-	705	600	26	-	-	843	320	535	3,868	2,866	34.9
2017	839	-	1,025	600	26	-	-	1,028	320	535	4,373	3,292	32.8
2018	1,039	-	1,025	600	26	-	-	1,168	620	635	5,113	3,751	36.3
2019	1,039	-	969	800	-	-	-	1,448	620	735	5,611	4,216	33.1
2020	1,039	-	969	1,000	-	-	360	1,728	620	735	6,451	4,755	35.6
2021	1,039	-	895	1,000	-	-	540	2,008	920	835	7,237	5,388	34.3
2022	1,039	1,000	895	1,000	-	-	540	2,008	920	835	8,237	6,048	36.2
2023	1,039	1,000	835	1,000	-	-	540	2,288	1,220	935	8,857	6,784	30.5
2024	1,039	1,000	1,155	1,200	-	-	720	2,708	1,220	935	9,977	7,608	31.1
2025	1,039	1,000	1,315	1,200	-	-	1,080	3,128	1,220	1,136	11,118	8,528	30.3
2026	1,039	2,000	1,315	1,600	-	-	1,080	3,548	1,220	1,336	13,138	9,556	37.5
2027	1,039	2,000	1,315	1,800	-	-	1,080	3,968	1,220	1,336	13,758	10,706	28.5
2028	1,039	2,000	1,315	2,000	-	-	1,260	4,340	1,820	1,636	15,410	11,994	28.5
2029	1,039	3,000	1,315	2,000	-	-	1,620	4,690	1,820	1,736	17,220	13,435	28.2
2030	1,039	3,000	1,635	2,000	-	-	1,980	5,110	2,420	2,036	19,220	15,026	27.9
2031	1,039	4,000	1,955	2,000	-	-	2,340	5,530	2,720	2,036	21,620	16,905	27.9
Total	**5%**	**19%**	**9%**	**9%**	**0%**	**0%**	**11%**	**26%**	**13%**	**9%**			

Source: (12)

On the other hand, the generated energy of the LCPDP was projected to grow steadily from 7160GWh in the base year to 105773GWh in 2031. Table 2 presents the LCPDP energy mix by fuel type.

Table 2: LCPDP Energy Mix (GWh)

Year	Hydro	Nuclear	HFO	Import	Baggase	GT-KER	GT-NGA	Geo	Coal	Wind	Total
2010	2,299	-	2,602	-	223	379	-	1,640	-	17	7,160
2011	2,335	-	2,620	-	223	393	-	1,640	-	17	7,228
2012	2,441	-	3,587	-	223	387	-	1,704	-	17	8,359
2013	2,441	-	5,170	-	223	301	-	2,000	-	472	10,607
2014	2,504	-	1,994	1,410	188	-	-	5,036	-	1,659	12,791
2015	2,540	-	2,649	1,426	194	-	-	6,949	139	1,660	15,557
2016	2,540	-	592	4,215	172	-	-	6,957	1,821	1,660	17,957
2017	2,540	-	1,512	4,317	183	-	-	8,473	1,941	1,660	20,626
2018	3,338	-	780	4,324	187	-	-	9,615	3,285	1,973	23,502
2019	3,338	-	472	5,445	-	-	-	11,898	2,975	2,286	26,414
2020	3,338	-	251	6,649	-	-	247	14,184	2,839	2,286	29,794
2021	3,338	-	192	6,781	-	-	312	16,470	4,066	2,600	33,759
2022	3,338	7,108	84	5,766	-	-	157	16,476	2,367	2,600	37,896
2023	3,338	7,174	113	6,038	-	-	221	18,762	3,941	2,913	42,500
2024	3,338	7,198	143	7,278	-	-	347	22,191	4,259	2,913	47,667
2025	3,338	7,199	279	7,417	-	-	856	25,619	5,184	3,540	53,432
2026	3,338	13,488	51	7,975	-	-	137	29,047	1,487	4,167	59,690
2027	3,338	13,908	97	9,704	-	-	389	32,478	2,788	4,167	66,869
2028	3,338	14,197	91	11,369	-	-	434	35,511	4,864	5,108	74,912
2029	3,338	20,924	82	10,861	-	-	512	38,364	4,410	5,421	83,912
2030	3,338	21,402	158	11,600	-	-	966	41,796	8,229	6,361	93,850
2031	3,338	28,464	178	11,509	-	-	1,226	45,228	9,469	6,361	105,773

Source: (12)

2.2 GREEN-LEAST COST GENERATION EXPANSION PLAN (GLCGEP) FOR KENYA

The GLCGEP capacity by fuel type was derived as shown in table 3. The results show that the generation capacity was 1382MW at a peak demand of 1227MW in the base year. This was predominated by hydropower (55%) and HFO (24%). In comparison to the rest of the planning period, the generation system had the least reserve capacity of 12.6%. The rising RE capacity additions at an average rate of 901MW per annum varied the system's capacity in the base year to 19828MW at 16905MW peak demand in 2031. By 2031, the generation capacity will be 78% RE and dominated by geothermal (40.8%) wind (19.2%) with a reserve of about 17%.

Table 3: *GLCGEP Capacity (MW)*

Year	Hydropower	Natural Gas	HFO	Nuclear	Imports	Bagasse	Kerosene	Geothermal	Solar PV	Wind	System's Capacity	Peak Load	% Reserve Margin
2010	761	0	332	0	0	26	60	198	0	6	1382	1227	12.6
2011	761	0	452	0	0	26	60	198	0	6	1502	1302	15.3
2012	761	0	452	0	0	26	60	626	0	6	1929	1520	26.9
2013	761	0	704	0	0	26	60	791	0	126	2466	1765	39.7
2014	814	0	704	0	0	26	0	1211	0	476	3229	2064	56.5
2015	839	0	704	0	0	26	0	1306	0	476	3349	2511	33.4
2016	839	180	704	0	0	26	0	1586	0	476	3809	2866	32.9
2017	839	360	704	0	200	26	0	1771	0	576	4474	3292	35.9
2018	1039	360	704	0	400	26	0	1771	0	676	4974	3751	32.6
2019	1039	360	648	0	800	0	0	1911	0	776	5532	4216	31.2
2020	1039	360	648	0	1000	0	0	2191	0	776	6012	4755	26.4
2021	1039	360	574	0	1200	0	0	2611	0	876	6658	5388	23.6
2022	1039	360	574	0	1200	0	0	2891	0	1376	7438	6048	23.0
2023	1039	360	514	600	1200	0	0	3031	100	1376	8218	6784	21.1
2024	1039	540	514	600	1400	0	0	3451	100	1476	9118	7608	19.8
2025	1039	540	461	600	1600	0	0	4151	100	1776	10266	8528	20.4
2026	1039	540	461	600	1600	0	0	4851	100	2176	11366	9556	18.9
2027	1039	1260	461	600	1600	0	0	5271	100	2376	12706	10706	18.7
2028	1039	1260	461	600	1800	0	0	6063	100	2876	14198	11994	18.4
2029	1039	1440	461	1200	2000	0	0	6763	100	2876	15878	13435	18.2
2030	1039	1980	461	1800	2200	0	0	7113	200	2876	17668	15026	17.6
2031	1039	2160	461	1800	2200	0	0	8093	200	3876	19828	16905	17.3
%	5.2%	10.9%	2.3%	9.1%	11.1%	0.0	0.0	40.8%	1.0%	19.5%	100%		

Source: (15)

The generated energy GLCGEP was projected to grow steadily over the entire planning horizon while meeting the requisite demand. Table 4 presents the GLCGEP energy mix by fuel type. The results show that the supply mix will rise steadily from 7721GWh in the base year to 105766GWh in 2031.

Table 4: *LCPDP Energy Mix (GWh)*

Year	Hydropower	Natural Gas	HFO	Nuclear	Imports	Bagasse	Kerosene	Geothermal	Solar PV	Wind (GWh)	System's Energy
2010	3352	0	2265	0	0	215	218	1649	0	22	7721
2011	3352	0	2742	0	0	217	64	1650	0	22	8047
2012	3352	0	936	0	0	124	1	4987	0	22	9422
2013	3352	0	802	0	0	112	0	6229	0	449	10944
2014	3533	0	24	0	0	2	0	7548	0	1693	12800
2015	3569	0	454	0	0	54	0	9796	0	1693	15566
2016	3569	222	397.39	0	0	75	0	12006	0	1693	17963
2017	3569	220	237.51	0	848	49	0	13652	0	2056	20632
2018	4479	292	292	0	1976	59	0	13986	0	2419	23503
2019	4479	165	124	0	3569	0	0	15297	0	2782	26416
2020	4479	179	136	0	4578	0	0	17639	0	2782	29793
2021	4479	137	95	0	4993	0	0	20910	0	3145	33759
2022	4479	199	166	0	5118	0	0	22974	0	4959	37895
2023	4479	184	150	3486	4499	0	0	24497	247	4959	42501
2024	4479	292	160	3540	5690	0	0	27935	247	5322	47665
2025	4479	197	98	3324	5458	0	0	33219	247	6411	53433
2026	4479	219	123	3196	5176	0	0	38378	247	7863	59681
2027	4479	855	216	3334	7030	0	0	42119	247	8589	66869
2028	4479	778	198	3246	7466	0	0	48092	247	10404	74910
2029	4479	659	136	6518	7408	0	0	54069	247	10404	83920
2030	4479	1124	181	10374	9183	0	0	57621	495	10404	93861
2031	4479	1592	246	10129	9555	0	0	65237	495	14033	105766
%	**4.2%**	**1.5%**	**0.2%**	**9.6%**	**9.0%**	**0**	**0**	**61.7%**	**0.5%**	**13.3%**	**100%**

Source: (15)

ISSN 2347-4289

3.0 Methodology

This was a comparative analysis study of the reference scenarios of the GLCGEP alongside the LCPDP for the 2011-2031 planning period the demand forecast held constant. It involved an assessment of the two generation expansion plans based on their relative installed capacity, energy & CO_2 emissions/credits and net present value (NPV). These criteria enabled the establishment of the competitive advantages of the GLCGEP over the LCPDP. The CO_2 emissions for the GLCGEP and the LCPDP were determined using the relevant emission factors from the 2014 US Climate Registry. In each scenario, the energy technologies considered varied in the emission factors based on their environmental pollution extents. Table 5 displays the emission factors for the energy generation technologies considered in the study.

Table 5: *Emission Factors for Generation Technologies*

SNo.	Energy Technology	TonCO₂/GWh
1	Coal	317.7424
2	Baggase	301.8014
3	Kerosene	246.8583
4	HFO	249.7988
5	Natural gas	181.2356
6	Geothermal	25.6918

The annual CO_2 emission for the given energy technology in the planning period was computed using equation (1).

$$AnnualEmission_{e\ technology}(tonCO_2) = \{G\_Energy_{e\ t}[GWh]\ X\ Emission\ Factor_{e\ t}\} \quad (1)$$

The total CO_2 emission for each technology in the period was established as the sum of the annual emissions in each generation expansion plan. The CO_2 difference between the plans was the avoided emissions that earned certified emission reduction (CER) at the rate of US$ 3.11 per ton of CO_2 emitted. This was the conservative prevailing carbon market rate at the time of this research.The NPV of the GLCGEP was extracted from [15]. Similar results were computed for the LCPDP for comparative analysis study.

4.0 Results

4.1 Capacity Mix

In the base year, the GLCGEP had an installed capacity of 1382MW; 19MW more than the LCPDP each against a peak demand of 1227MW. Figure 1 shows the generation capacities for the GLCGEP and the LCPDP. In these figure, the results show that the GLCGEP and the LCPDP were both predominantly hydropower (55%) and HFO (24%). None had natural gas, nuclear, imports, solar PV and coal generation plants.

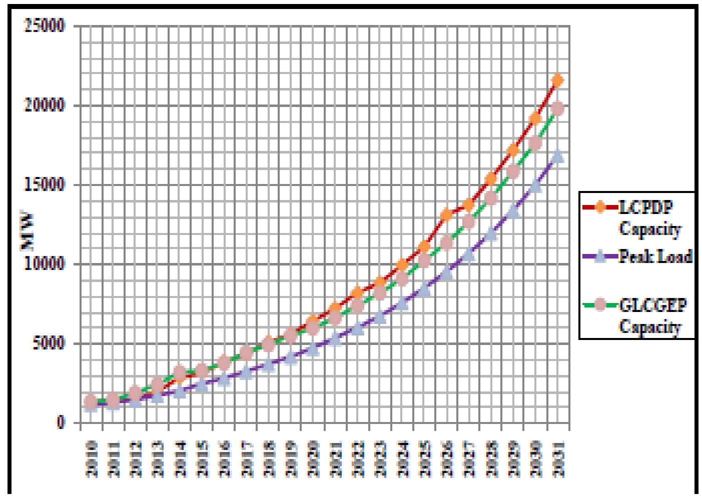

Figure 1: *OGLCGEP and LCPDP Generation Capacities*

Additionally, the increasing annual capacity additions over the same planning period were projected to vary the GLCGEP to 19828MW against a peak demand of 16905MW with average reserve margins of 25% by 2031. On the other hand, the LCPDP would rise to 21620MW at 28% average reserve margins; 1792MW capacity higher than the GLCGEP against the same peak demand. Apparently, these LCPDP capacity growth trends will provide excess capacity from 2018 onwards over the peak demand unlike the GLCGEP. By the end of the planning period, geothermal generation will dominate both the GLCGEP (40.8%) and the LCPDP (25.6%). However, its capacity will be 2563MW higher in the GLCGEP. Wind was the other fairly predominant generation plant at 19.5% (GLCGEP) and 9% (LCPDP). On the contrary, the major fossil power generation from coal at 2720MW and net HFO at 1494MW in the LCPDP would prevail over the GLCGEP. Subsequently, the GLCGEP will be highly integrated with renewable energy (RE) hence 78% green while the LCPDP 49% green by 2031.

3.2 Energy, CO_2 Emissions & Credits

The planned energy system for the GLCGEP would supply 7721GWh in the base year steadily rising to 105766 GWh 2031. This will be unlike the LCPDP which will supply 7160GWh to 105773 GWh during the same period. Consequently, the two energy systems emitted varied CO_2 emissions due to their different generation capacity portfolios. Figure 2 presents the CO_2 emission profiles for the GLCGEP and the LCPDP.

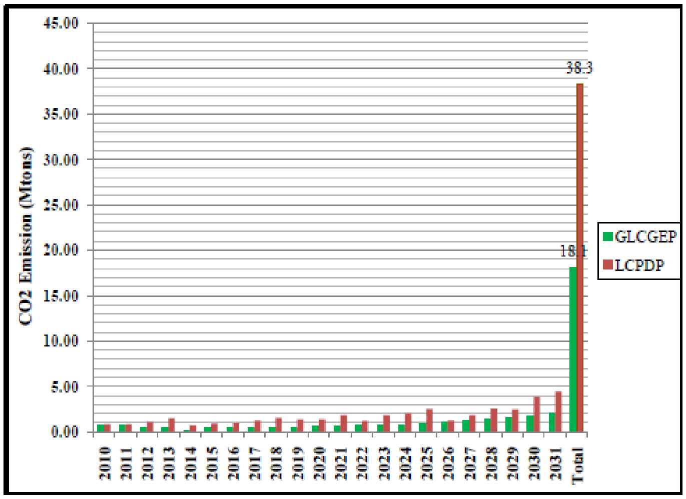

Figure 2: *GLCGEP and LCPDP CO_2 Emissions*

The results show that in 2014, the GLCGEP emitted about 0.2 $MtCO_2$; one third of the LCPDP. This was the lowest emission for each case during the entire planning period. The trend over the planning duration shows a higher rate of emissions from the LCPDP than the GLCGEP. In 2031, the GLCGEP will emit about 2.0 $MtCO_2$ approximately half of the LCPDP emissions. This will be the highest probable emissions from the GLCGEP over the planning period. In total, the GLCGEP will emit 18.1 Mt CO_2 lower compared to 38.3 $MtCO_2$ from the LCPDP. Consequently, there will be significant annual net avoided emissions on the GLCGEP over the LCPDP. Table 6 presents the avoided CO_2 emissions and carbon credits on the GLCGEP. On aggregate, a total of 20.2 Mt CO_2 avoided CO_2 emissions will be realized worth US$ 62.9 million on the GLCGEP.

Table 6: *Avoided Emisssion & Carbon Credits*

Year	GLCGEP Avoided CO_2 Emissions (ton.)	Carbon Credits (US$) Earned
2010	126109.6	392200.86
2011	52294.9	162636.99
2012	703036.0	2186441.99
2013	1090274.8	3390754.63
2014	483700.8	1504309.55
2015	561582.2	1746520.60
2016	486545.4	1513156.22
2017	802616.5	2496137.30
2018	1039097.7	3231593.98
2019	914984.4	2845601.49
2020	854357.5	2657051.77
2021	1233817.2	3837171.61
2022	557056.3	1732445.23
2023	1102345.0	3428292.88
2024	1211414.2	3767498.03
2025	1616568.7	5027528.75
2026	199906.3	621708.61
2027	523990.0	1629608.87
2028	1133198.7	3524247.88
2029	957625.0	2978213.65
2030	2173752.2	6760369.46
2031	2411320.7	7499207.29
Total	20235594.1	62932697.7

4.3 Generation Economics

The relative energy system's cost and net present value (NPV) for system expansion for the GLCGEP and the LCPDP were studied. Table 7 shows the financial inflows & outflows for the GLCGEP and the LCPDP. The results show that the energy system's cost for the GLCGEP will be consistently higher that corresponding values in the LCPDP from the base year to 2031.

Table 7: *LCPDP Energy Mix (GWh)*

Year	GLCGEP (US$ Billions)				LCPDP (US$ Billions)			
	PV - Inflow	Salvage Value	System's Cost	NPV	PV - Inflow	Salvage Value	System's Cost	NPV
2031	15.70	1.09	14.62	2.16	12.54	0.34	13.18	-0.30
2030	13.93	0.89	14.08	0.74	11.13	0.30	12.68	-1.25
2029	12.45	0.93	13.48	-0.10	9.95	0.28	12.19	-1.96
2028	11.12	0.74	12.83	-0.97	8.88	0.33	11.68	-2.46
2027	9.92	0.42	12.14	-1.79	7.93	0.19	11.12	-3.00
2026	8.86	0.58	11.52	-2.09	7.08	0.19	10.58	-3.32
2025	7.93	0.54	10.76	-2.30	6.34	0.20	10.01	-3.48
2024	7.07	0.31	9.93	-2.55	5.65	0.12	9.36	-3.59
2023	6.31	0.58	9.23	-2.34	5.04	0.13	8.80	-3.62
2022	5.62	0.32	8.25	-2.31	4.49	0.26	8.17	-3.42
2021	5.01	0.26	7.43	-2.16	4.00	0.12	7.28	-3.15
2020	4.42	0.15	6.62	-2.05	3.53	0.09	6.53	-2.90
2019	3.92	0.11	5.98	-1.95	3.13	0.09	5.83	-2.61
2018	3.49	0.17	5.38	-1.72	2.79	0.12	5.06	-2.14
2017	3.06	0.10	4.74	-1.58	2.45	0.01	4.08	-1.63
2016	2.67	0.12	4.08	-1.30	2.13	0.00	3.61	-1.48
2015	2.31	0.05	3.29	-0.93	1.85	0.06	3.31	-1.41
2014	1.90	0.00	2.83	-0.93	1.52	0.01	2.52	-1.00
2013	1.62	0.00	2.70	-1.08	1.26	0.00	2.07	-0.81
2012	1.40	0.11	2.54	-1.03	0.99	0.00	1.74	-0.74
2011	1.19	0.00	1.16	0.03	0.86	0.00	1.13	-0.27
2010	1.15	0.00	0.74	0.41	0.85	0.00	0.75	0.10

However, the trends in the net revenue accrued show that the GLCGEP's energy system will grow towards a net positive NPV at a higher rate than that of the LCPDP. In fact, the GLCGEP will cross the zero NPV between 2029 and 2030 while the LCPDP will remain in the negative NPV even at the end of the planning period. The GLCGEP will have an NPV of US$ +2.16 billion unlike the US$ -0.31 billion for the LCPDP by 2031.

5.0 Discussions

Comparatively, both generation expansion plans will have the capacity to meet the requisite energy demand as evident in figure 1. However, the LCPDP at 28% reserve margins on average will consistently provide excess capacity from 2018 to the end of the planning period. Consequently, probable idle capacity would prevail if proper plans were not in place for excess capacity utilization. According to [3], [5], [6], a 15-25% reserve margin was modest for sound reliability. Thus, the GLCGEP's 25% will be sufficient for the prevailing demand without excess idle capacity like the LCPDP. As a matter of fact, no planned energy system was absolutely emission free as both generation plans depicted significant emission profiles. Since, the GLCGEP had more integration of RE than the LCPDP; it was projected to emit lower CO_2 emission than the LCPDP. In figure 1, it was shown that the GLCGEP will emit 18.1$MtCO_2$ compared to 38.3Mt CO_2 for the LCPDP by 2031. Consequently, an estimated 20.2 Mt CO_2 of avoided emissions on the GLCGEP will prevail on the envisaged system over the LCPDP's system. According to Shende *et al*. (2014), the avoided emissions on the system will generate carbon credits entitled certified emission reduction (CER) traded on the carbon market at prevailing rates. Without, the energy system in the GLCGEP will present more business opportunities to the Kenya's generation sector arising from carbon credits similar to the ones acknowledged by [7], in India. According to the researcher, through the CDM under the Kyoto Accord, numerous RE projects for enhancing environmental sustainability can be developed. Thus, the GLCGEP with an integration of 78% RE encompass potential projects similar to those documented by [8], [9] for CDM candidacy. Nevertheless, low carbon credits' revenue due to low carbon market prices discourages implementation of CDM in many countries as observed by [9]. The researcher further includes other shortcomings like the long periods for validation, registration and issuance of the CERs for CDM projects take and fraud & forgery of CDM projects. These challenges besides theUS$62.9 million carbon revenue over the 22 year planning period from the GLCGEP will be a great hindrance to Kenya's quest for green generation growth via CDM. However, from literature by [5]; [10], [11]; numerous RE generation benefits such are green jobs, health benefits and foreign exchange earning & savings were forthcoming for green growth in developed and developing countries. Thus, the 'green' fringe benefits will top-up the meagre carbon revenues to an invaluable price for the low carbon Kenya pending the resolution of the carbon market bottlenecks by relevant stakeholders. The RE based GLCGEP energy system will be a rather costly than the LCPDP in terms of system's cost because traditionally RE have higher upfront investments costs. Nevertheless, RE generation portfolio effectively minimized the cost by generating higher revenues from its investment. This was why the GLCGEP was projected to generate consistently higher NPVs than the LCPDP throughout the planning horizon. Notwithstanding, the invaluable economics of the green generation investments were not accounted in this NPV computation. At an NPV of US$ +2.16 billion unlike the US$ -0.31 billion for the LCPDP by 2031, the energy system envisaged in the GLCGEP was more feasible. These project characteristics' of a higher and positive NPV for the system was consistent with [3], [5], [6] remarks on economic evaluation of feasible projects.

6.0 Conclusion and Recommendation

Comparatively the envisaged energy system in the GLCGEP was a better compromise against the LCPCP because over the planning period, it was projected to have more reasonable average reserve capacity of 25%, ample social-economic opportunities for green growth and more than US$ 2.16 billion net revenues on the generation investment. As a matter of fact, the green-based generation expansion projects will be feasible and sustainable GENCOs in the long-run. In this case, the way to go will be planning to generate green power for security of supply and sustainable development. Therefore, the research recommends future studies to focus on modelling of Kenya grid reliability and stability with high penetration of variable renewable energy sources.

Acknowledgment

I would like to thank Dr. Oliver Johnson of the Stockholm Environmental Institute (SEI); Nairobi for his mentorship during the preparation of this paper. I also acknowledge the support provided by the SEI Write-shop to Support Developing of Country Publications on Transitions to Modern Energy Systems in which this paper was chosen. I declare that there was not conflict of interest in this research.

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ISSN 2347-4289

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