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Energy-Mix Dynamic for Optimization of Power Generation Strategy and Expansion In A Developing Economic Growth

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Abstract- *The paper formulated the framework of energy mix dynamic for generation expansion and economy growth particularly the burning of fossil fuel which have significant influence on global climate. That is effective mitigation of climate change will require deep reduction in greenhouse gas emissions. Since, Nigeria is richly endowed with both fossil energy resources such as crude oil, natural gas, coal and renewable energy resources like solar, wind, biomass, biogas etc. Essentially conventional energy resources has continuously remained the major sources for energy consumption. This mean that modelling of wind-speed variation is another form of energy generation which is an important requirementfor the estimation of wind energy potential at many locations. Inability of power systems to supply in a developing countries needsto generate enough electric power but due to poor supplyhas led to extra-ordinary power losses on the system due to over load dependence thereby making the power system planning and running cost outrageous. This technical paper considered the application of decomposition technique on the view to analyse the capacity combination of generating plant into various options for an optimization search in order to look out for the best capacity options for the optimal operational fuel cost and energy saving. Similarly, two parameters weilbull statistical distribution areused to determine the shape and scale parameters of wind speed (m/s). The forecasted load or energy demand for twenty (20yrs) projection was determined, which served as the input data for the capacity allocation to the generating stations especially in Nigeria which include the following capacities of generating stations:2250MW for Afam power, 2350MW for Sapele power and 3000MW to Egbin power as expected power to be generated from these stations. The study also examined the existing capacity of the generating stations and considered a capacity-mix combination: (200MW, 250MW and 300MW) as row-element matrix operation while the column-element matrix need to be determined or factor-out into different number of unit combination arrangement to achieve different options for the best selection. The row and column capacity arrangement are implemented into the decomposition equation in order toanalyse the break-down of capacity – allocation into different unit-combination which evidently substituted into the cost equations to derived financial objectives on the view to make a savings. Five optimization plans was developed with respect to five different number of unit-combination arrangement in order to have a total operational cost of the following: ₦8,176,503,40,800, ₦7,654,267,24,800, ₦7,499,530,60,800, ₦7,460,846,44,800 and ₦5,206,095,83,900. The research paper strongly identified relationship between capacity and cost this shows that as the capacity of the generating plant increases the operational running cost of the power plant also increases this is being validated with two-tail test and spearman's rank correlation coefficient with (* R_k *: 0.99375) approximately +1 which shows that there is a correlation that exist between capacity and cost.The studyalso considered a stand-alone diesel generator system* *being operated in remote communities of Niger Delta region of Nigeria in areas not accessible to grid using the integration of renewable energy system with a view of determine an optimal system design that will be most technically and economically feasible and efficient with considerable environmental impact, PV system was designed and component sizing were performed. Diesel generator, PV-Battery and PV-Diesel hybrid systems were simulated and analysed based on the operational behaviourof economic and environmental constraints. The results shows that PV Battery system has high capacity of renewable penetration with no emission which made it most environmentally friendly than other systems. Diesel generator recorded the highest emission into the environment with highest fuel consumption. The PV-Diesel hybrid system had 86.6% PV penetration and shows more benefit of cost saving, emission reduction without compromising reliability over the projected life of 20 yearswas determined. Evidently, modeling of wind turbine in a tropical variation is an essential requirement in the estimation of wind energy potential utility in the tropical site for turbine power generation,the wind energy potential in Kwara State (Lat. 7.43^{o}N; Long. 3.9^{o}E; Alt. 227.2m) is analyzed using daily wind data for 10 years (2000 - 2010) obtained from the International institute of Tropical Agriculture (IITA), Kwara,Nigeria. The daily, monthly, seasonal and yearly wind speed probability density distributions are modeled using Weibull Distribution Function. The measured annual mean wind speed in Kwara is 2.75 ms^{-1}, while the mean wind speed and the power density function are 2.947 m/s and 15.484Wm^{-2} respectively however Kwara State can be classified as a low wind energy region.*

Index Terms: *optimization planning, generation expansion, decomposition techniques of electric power, profit, Photovoltaic hybrid, wind speed, renewable energy, Weibull distribution function*

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I. INTRODUCTION

Considering the growing energy demand, increasing diversities of services and advances in generation, transmission and distribution system which are prompting industries/companies, private-sector, individuals etc.[1] to rapidly expand and modernize their networks in order to satisfy the consumer [2].

The main function of a power generating station is to deliver power to the targeted number of consumers. However, the electric power demand of different consumers vary in accordance with their level of activities [3].

Most of the complexities of modern power plan-operation gave rise from the inherent variability of the load demand users. Unfortunately power engineers would like the operations of alternators in the power station to run at their rated capacity for purpose of maximizing efficiency.

Optimization of electric power generation for expansion planning can be solved from one period to the next in a consistent and continuous programme for different look-ahead periods. This paper presented a simple decomposition technique that would strongly put into considerationthe planning programme of the load forecast-result (for energy demand) with the aim of minimizing cost and maximizing profit[6].

Recent research studies shows that more than 1.6 billion people in the world do not have access to electricity and majority of these people are rural dwellers of the developing countries, where the pace of electrification remains slow [1]. Majority of the Nigerian citizens are rural dwellers where there is difficult terrain no easy access to fuel and electricity grids. These communities are located at long distance from the nearest connection point of a utility grid system. Some of the rural communities are characterized byvery low population density, low level of education and low load density. Rural electrification form an integral part of a country's infrastructure, although the infrastructural economic plans for developing countries have not given it sufficient priority. Electricity is one of the primary inputs for economic and social development since its provision is crucial for improving living standards, supporting the development and fostering social activities [3]. Electricity provided to rural communities can increase the quality of life. [4].

Nigeria is richly endowed both fossil energy resources (such as crude oil, natural gas, coal) and renewable energy resources like solar, wind, biomass, biogas, etc. for many decades fossil fuels and firewood (conventional energy resources) have continually remained the major energy resources which amount to 90% of the national energy consumption [7]. However, in recent times, there has been a continual decline in supply of conventional energy due to the depletion of the national reserve while the demand has continued to increase resulting in energy crisis with incessant power outages. The environmental pollution and health hazards associated with the use of fossil fuels are another driving force towards the global switch to renewable energy.

Essentially, wind energy is characterized as high variability in space therefore it is very important to describethe variation in wind speed for optimizing the design of the system in order to reduce energy-generating costs [7].

Similarly, number of studies have been carried out on the assessment of wind speed characteristics in some locations in Nigeria different analytical tools such as statistic models including Weibull and Rayleigh distribution functions, stochastic simulation, seasonal autoregressive integrated moving average model linear and multiple regression models and artificial neural network models.

In the modeling of wind speed variation much consideration has been given to the Weibull two-parameter (shape parameter, k and scale parameter, c) function because it has been found to fit a wide collection of wind data [7].

The sustainability of entrepreneurship development of a given nation rely on the availability of renewable energy sources as an alternative processes for energy consumption accessibility.

Following to the abundant endowment with natural resources in Nigeria having primary sources of energy which includes, Oil, gas, coal, solar, hydro, biomas and wind etc.

The percentages utilization of these natural resources varies in there respective capacities/usage, especially crude oil and natural gas (coal, hydro-power etc).

Dynamic of Energy mix Technology

Over dependence and concentration of natural resources on hydrocarbon fossil fuel (oil) and gas with little or less concentration on coal, hydro power plants supply as a form of energy-mix power generation for efficient utilization are considered as driver for economic development.

Table 1: Energy Mix Scenario's (Renewable Energy/ Non-renewable energy)

S/No	Selected State	Area (Km^2)	Windy Area %	Potential Capacity (MW)	Generation Potential (Mwh/yr)
1	Adamawa	37,957	45	854	2244
2	Bauchi	48,197	50	1204	3166
3	Borno	72,767	100	3638	9561
4	Gombe	17,428	100	871	2290
5	Jigawa	23,415	100	1170	3070
6	Kaduna	44,217	60	1326	3486
7	Kano	20,389	90	917	2411
8	Katsina	23,822	100	1191	3138
9	Kebbi	36,320	25	454	1193
1	Plateau	26,539	90	1194	3138
1	Sokoto	32146	90	1446	3801
1	Taraba	59,180	40	1183	3110
1	Yobe	44,880	100	2244	3539

Sources: Meteorological Agency, Nigeria

Table 2:Small Hydro Power generation

S/No	Selected State	Area (Km^2)	Windy Area %
1.	Lower Benue	Benue	69.2
2.	Chad	Bornu	20.8
3.	Upper Benue	Bauchi	42.6
4.	Upper Benue	Gongola	162.7
5.	Lower Benue	Plateau	110.4
6.	Niger	Kaduna	59.2
7.	Niger	Niger	117.6
8.	Cross Rivers	Rivers	258.1
9.	Hadeija-Jamaare	Kano	46.2
10.	Niger	Kwara	38.80
11.	Sokoto-Rima	Katsina	8.0
12.	Sokoto-Rima	Sokoto	30.6

Sources: Meteorological Agency, Nigeria

Benefits derivable in the utilization of energy mix for power generation considered;

(i) Available wind speed (m/s) in geographical locations which are simulated to determine the capacity of wind-turbine generator (WTG) for Economic growth and development.

(ii) Available solar radiant energy in the locality are simulated/generated for the capacity of pv/solar panel energy availability for economic growth and standard of living.

(iii) Mix-energy resources as an alternative processes for energy generation and utilization are necessary consideration to increase the economic activities in the commercial, industrial and residential level.

Therefore sustainability for economic development of a given nation depends on the availability of renewable energy resources as an alternative for the consumption of energy accessibility.

II. BACKGROUND OF THE STUDY

Electric Power Generation Expansion Planning

Ideally, the power system planning and operation identified strongly the generation expansion planning (GEP), transmission expansion planning (TEP) and Distribution-Expansion Planning (DEP) respectively. This research work focuses on the Energy-mix dynamics which is about engaging the current and the future states of a power system, therefore information of the existing state of the system would seriously give an insight for proffering solution with good engineering decision. Evidently, this processesis aimed to decide on new plan (generation expansion) as well as upgrading existing system elements to adequately satisfy the loads requirements for the future expansion, the elements includes:

(i)Generation facilities
(ii)Substations
(iii)Transmission line/and or cables
(iv)Capacitors/Reactors etc.

Nigeria in particular, the power supply from the central grid is either not available or unreliable. Solar energy resources in Nigeria can be harnessed to generate electricity for rural electrification. This can enable communities in the remote areas of difficult topographic terrain, where construction of transmission line is not economically viable on the view to assess power supply from Renewable Energy Resource (RES). This has become an important alternative as power provider in the rural systems.[5]. Introduction of RE provides good opportunity for effective energy decentralization and security to both rural and urban citizens. This could be applicable and carried out through distributed generation, solar PV, wind, biomass, and diesel operated hybrid-microgrid system.

III. MATERIALS AND METHOD

Decomposition Technique (Row-column matrix)

This is a mathematicaloperation of matrix multiplicationwhich occurs in engineering problem formulations as;

– If A is a row matrix that is : $\left| a_1, a_2, a_3 \right| \Rightarrow \quad row \quad arrangemen \quad t$

Similarly,

- If B is a column matrixthat is :

$$\begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \Rightarrow \quad \text{column arrangement}$$

– This evidently means that,

$$[A] = [a_1, a_2, a_3] \tag{1}$$

$$[B] = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} \tag{2}$$

– In a similar manner, matrix [B] can also be rewritten as:

$$[B] = [b_1, b_2, b_3]^T \tag{3}$$

– By multiplication operation by matrices operations whichcan be decompose the matrices [AB] as:

$$[A\,B] = [a_1, a_2, a_3][b_1, b_2, b_3]^T \tag{4}$$

$$[A\,B] = \underbrace{[a_1, a_2, a_3]}_{\text{Capacity (MW)}} \overbrace{\begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}}^{\text{Units}} \tag{5}$$

Hence, the decomposition by multiplication operation of matrix [AB] can be rewritten as:

$$[A\,B] = \sum_{i=1}^{n} A_i B_i = \begin{bmatrix} a_1 b_1 + a_2 b_2 + a_3 b_3 + \\ \text{..........} \ldots + a_n b_n \end{bmatrix} \tag{6}$$

– Sixteen (16) generating stations were captured in a developing country like Nigeria as a study case, while some generating stations are under proposed constructions for expansion processes. Specifically, forpurpose of this paper three (3) generating stations were considered as case studies: Afam Power Station, Sapele power station and Egbin power generating station.

3.1 CAPACITY COMBINATION ANALYSIS

Analysis 1: Afam generating power station

(i) Theanalysis rely on the installed capacity.
(ii) Thermal power station
(iii) Existing capacity = 980 MW
(iv) Capacity addition due to the twenty years projection= 2250MW

Analysis2: First optimization plan
Capacity combination (MW)
(number of generation plant) Unit

$$\underset{\downarrow}{[200 \quad 250 \quad 300]} \qquad \underset{\downarrow}{[1 \quad 7 \quad 1]^T}$$

The decomposition operation becomes:

$$[2250 \ MW] = \underbrace{[200 \quad 250 \quad 300]}\begin{bmatrix}1\\7\\1\end{bmatrix} \tag{7}$$

$$= 200 \times 1 + 250 \times 7 + 300 \times 1$$

$$= 200 + 1750 + 300$$

$$= \underline{\underline{2250 \ MW}}$$

Analysis 3: Determination of the input-output curve of a generating unit from heat rate curve given as:

$$F_i(PG_i) = PG_i \ H_i(PG_i) \tag{8}$$

The input-output of a generating unit specifies the input energy rate, $F_i(PG_i)$ in joule/hour cost of fuel used per hour $C_i(PG_i)$ in ₦/hr given as function of the generator power output (PG_i).

where:

$F_i(PG_i)$: The graph of input-output curve of input-energy rate.

$H_i(PG_i)$: The heat-rate in J/MWH or J/hr.

PG_i: The output power (MW)

Analysis 4: Determination of input-energy-rate, $F_i(PG_i)$, the heat-rate-curve function can be approximated in the form as:

$$H_i(PG_i) = \frac{\alpha}{PG_i} + \beta + \gamma PG_i (J / MWH) \tag{9}$$

The assumption for the coefficient are positives.
To establish and obtained the expression for input-energy rate, $F_i(PG_i)$ from equation (8) and (9) are given as:

$$F_i(PG_i) = PG_i \ H_i(PG_i) \text{ and} \tag{10}$$

$$H_i(PG_i) = \frac{\alpha}{PG_i} + \beta + \gamma \ PG_i \tag{11}$$

The fuel cost equation represents as:

$$C(PG_i) = F_i(PG_i) \tag{12}$$

Similarly,

$$Fi(PGi) = PGi \ \ Hi(PGi) \tag{13}$$

Substitute $F_i(PG_i)$ into equation(12)to obtain as:

$$C(PG_i) = F_i(PG_i) = PG_i \ H_i(PG_i) \tag{14}$$

Substituting $H_i(PG_i)$ of equation (10) into equation (8)to obtain as;

$$F_i(PG_i) = PG_i\left(\frac{\alpha}{PG_i} + \beta + \gamma PG_i\right) \tag{15}$$

and

$$F_i(PG_i) = \alpha + \beta PG_i + \gamma P^2 G_i\,(J/h) \tag{16}$$

Equation (16) defined as the quadratic expression for input energy rate, $F_i(PG_i)$.

Analysis 5: Determination of fuel cost-equation, $C_i(PG_i)$

If the cost of fuel is ₦/Joule, then multiplythe fuel-input rate, $F_i(PG_i)$ by the cost of fuel per joule given as ₦/joule in order, to obtain the fuel cost as $C(PG_i)$;

Recall equation (16) given as;

$$F(PG_i) = \alpha + \beta PG_i + \gamma PG_i^2 \quad (J/h) \tag{17}$$

Thus, eventually becomes;

$$C(PG_i) = \alpha + \beta PG_i + \gamma PG_i^2 \quad (J/h) \times (₦/J) \tag{18}$$

or $C(PG_i) = \alpha + \beta PG_i + \gamma PG_i^2 \quad (₦/hr)$

Analysis 6: Cost Data Analysis for generating Capacity and fuel consumption pattern.

Determination of fuel-consumption coefficient (α, β, γ) from heat-rate equation $H(PG_i)$.

Analysis 7: Three (3) thermal generating stations were captured: Afam, Sapelle and Egbin power generating station for Analysis.

Analysis 8: Generating power plantUnits capacity combination for the power stations includes: 200MW, 250MW and 300MW represented as $(PG_1, PG_2 \text{ and } PG_3)$ respectively,

Analysis 9: The heat-rate capacity of the generating plants are:

$$\left.\begin{array}{ll} PG_1 = 200\ MW & (10\ J/MWH) \\ PG_2 = 250\ MW & (9\ J/MWH) \\ PG_3 = 300\ MW & (10\ J/MWH) \end{array}\right\} \tag{19}$$

Analysis 10: Analysis for different loadingcondition

Generators (PG_1, PG_2, PG_3), and percentage (%) capacity loading condition are: 25%, 40% and 100% respectively.

Analysis 11: Capacity Combination Analysis for Afampower generating station:

The investigation and analysis rely on installed capacity.

Existing capacity = 980MW

Capacity addition due to the twenty year projection = 2250MW.

Analysis 12: Expressing the heat-rate equation in terms of the threegenerators, $H(PG_1)$: $H(PG_2)$ and $H(PG_3)$, given as:

$$H(PG_1) = \frac{\alpha_1}{PG_1} + \beta_1 + \gamma_1 PG_1 \tag{20}$$

$$H(PG_2) = \frac{\alpha_2}{PG_2} + \beta_2 + \gamma_2 PG_2 \tag{21}$$

$$H(PG_3) = \frac{\alpha_3}{PG_3} + \beta_3 + \gamma_3 PG_3 \tag{22}$$

Where;

$$\left.\begin{array}{l} H(PG_1) = 10\ J/MWH \\ H(PG_2) = 9\ J/MWH \\ H(PG_3) = 10\ J/MWH \\ PG_1(25\%\ \text{loading}) = 562.5\ MW \\ PG_2(40\%\ \text{loading}) = 562.5\ MW \\ PG_3(100\%\ \text{loading}) = 2250\ MW \end{array}\right\}$$

Analysis 13: Determination and Substituting data into equation (20, 21 and 22) respectively;

This implies as:

$$10\ J/MWH = \frac{\alpha_1}{563} + \beta_1 + \gamma_1 \times 563 \quad (23)$$

$$9\ J/MWH = \frac{\alpha_2}{900} + \beta_2 + \gamma_2 \times 900 \quad (24)$$

$$10\ J/MWH = \frac{\alpha_3}{2250} + \beta_3 + \gamma_3 \times 2250$$

(25)

Arranging the algebraic equations given as;

$$10 = 0.001776\ \alpha_1 + \beta_1 + 563\ \gamma_1 \quad (26)$$

$$9 = 0.00111\ \alpha_2 + \beta_2 + 900\ \gamma_2 \quad (27)$$

$$10 = 0.00444\ \alpha_3 + \beta_3 + 2250\ \gamma_3 \quad (28)$$

Analysis 14: Recall the fuel–consumption coefficient (fuel – cost parameters) using determinant by matrix technique given as:

α, β,γ as :

$$\left.\begin{aligned} \alpha &= 2506.69 \\ \beta &= 4.418 \\ \gamma &= 0.00184 \end{aligned}\right\} \quad (29)$$

Analysis 15: The capacity combination analysis for Afam power generating station in Nigeria given as:

$$[PG_1, PG_2, PG_3] = [200 \quad 250 \quad 300] \begin{bmatrix} 1 \\ 7 \\ 1 \end{bmatrix}$$

$$= 200 \times 1 + 250 \times 7 + 300 \times 1 = 2250\ MW \quad (30)$$

Analysis 16: Implementing the optimization techniquesfor expansion planning and economic growth given as:

$$C_i(PG_i) = \alpha + \beta PGi + \gamma PG_i^2 \quad (\$ / hour \quad or \quad ₦/h) \quad (31)$$

Analysis 17: Substitute the variables, $PG_1, \alpha, \beta, \gamma$ into the cost function equation (17) given as:

$$PG_1 = 200 \times 1 = 200\ MW \quad or$$

$$PG_1 = 200\ MW \quad (32)$$

Thus,

$$C_1(200\ MW) = 2506.69 + 4.418 \times 200 + 0.00184 \times (200)^2 \ or\ C_1(200\ MW) = 2506.69 + 883.6 + 73.6$$

$$C_1(200\ MW) = 3,463.89\ \$/hour \quad or \quad (33)$$

$$C_1(200\ MW) = 692,778\ ₦/hour$$

Similarly, for capacity of generator (PG_2), given as;

PG_2 = 250 × 7 = 1759MW or

PG_2 = 1750MW, α = 2506.60,

β = 4.418, γ= 0.00184 (34)

This implies,

$$C_2(1750\ MW) = 2506.69 + 4.418 \times 1750 + 0.00184 \times (1750)^2$$

$$\left.\begin{aligned} &= 2506.69 + 7731.5 + 5635 \\ C_2(1750\ MW) &= 15,873.19\ hour \quad or \\ C_2(1750\ MW) &= 3,174.638\ ₦/hour \end{aligned}\right\} \quad (35)$$

Solvingsystematically for PG_3 given as:

PG_3 = 300 × 1 = 300MW

where,

PG_2 =300MW, α = 2506.60,

β = 4.418, γ= 0.00184

Thus,

$$C_3(300\ MW) = 2506.69 + 4.418 \times 300 + 0.00184 \times (300)^2 \ or \quad (36)$$

= 2506.69 + 1325.4 + 165,6or

$C_3(300\ MW) = 3{,}997.69\ (\$/hour)$ $C_3(300\ MW) = 799{,}538\ ₦/hour$

Analysis 18: Determination of total cost (n) for the optimization plan–1 for the capacity combination strategy given as:

$n_1 = C_{T1} = C(200\ MW)_1 + C(1750)_2 + C_3(300\ MW) \quad = 4{,}666{,}954\ ₦/hour$

Therefore, for 20 year - projection hours = 20 x 8760 hours
= 175,200 hours

This mean that $n_1 = 4{,}666{,}954\ ₦/hour \times 175{,}200$

n_1=₦817650340800 (37)

Data required for the analysis and investigations include solar irradiation, ambient temperatureand energy demand. The solar irradiation and ambient temperature data were accessed from NASA database. The electrical load profile data was gathered from an individual household appliance.

Technique of for PV/Solar System

For a successful sizing and optimization of a microgrid certain considerations were made.

Identifying Energy Reserve and Energy Demand Projection

The solar irradiation, ambient temperature data of the study zone were accessed from the NASA database and considered to ensure that they are sufficient for adequate power generation.

Equipment Sizingfor PV/Solar System

System component sizing and values were calculated using deterministic method. Relevant data available from load profile and renewable energy sources were applied in the modeled equations arising from theoretical analysis. Relevant component values include PV power rating and required generation capacity, battery bank capacity, converter and their capacities.

Microgrid Sizingfor PV/Solar System

The Homer simulation tool was used for the optimization of system designs. The values derived from equipment sizing, solar irradiation, ambient temperatureand load profile form the input parameters for the simulation software tool. Different energy system configurations were simulated to determine the optimum hybrid system based on power balance, technical option, cost and specifications to select the optimum scenario according to the isolated community

Identifying Energy Resources*for PV/Solar System*

Solar radiation data was obtained from NASA's PVGIS database. Once calculated on horizontal area, daily solar irradiation varies from 3.6 kWh/m^2/d in July to 5.4 kWh/m^2/d in February etc with an annual average of 4.53 kWh/m^2/d are determined.

Ambient Temperature which is the temperature of the immediate surroundings of the PV module. It has relative effect on the PV cell temperature which affects the performance of the PV systems.

Due to unavailability of measured values of ambient temperature this it can rely upon on the data obtained from NASA website. The monthly maximal average temperature is 33.3°C in March while the minimal average temperature is 21.0 °C in September which makes an annual average of 26.4 °C.

Case A: Energy Demand Estimation

A design margin (K_d) was used to account for any potential inaccuracies in estimating the loads, allow future loads to be supported, system losses and intermittent appliances' startup and shutdown surge

That is if the peak demand power is 61.12 KW

$$\text{Load factor (L.F)} = \frac{E_d}{P_p * 24hours} \quad (38)$$

Where P_p: is Peak power
Ed : Energy demand

$$\text{Load factor (L.F)} = \frac{984.7}{61.12 \quad *24hours} = 0.6 \qquad (39)$$

Case B: PV Array Preliminary Sizing for PV/Solar System

Calculation of PV array size which will be used to determine the input values for the simulation and optimization part.

There are three parameters featured which are contained as;

(i) Peak Sun Hour (PSH)
(ii) Average daily load (ADL)
(iii) Operation ratio (OR)

The first two parameters were obtained from (*PVGIS-CMSAF database Online, 2019*) for the study. The PSH parameter represents the irradiation on the horizontal plane. The average daily load, for each month is calculated from the consumption data collected from the study. The operation ratio is a basic value for sizing a PV system for the "design month" which is the month with highest ratio of load to insulation. The ratio between the average daily load and PSH corresponds to August as the highest ratio so that the system must be designed to accommodate the energy needs of this month.

To determine the power needed to accommodate the load even at the least PSH the equation are given as:

$$P_{pv} = \frac{E_{LoadTotal}}{PSH.PR} \qquad (40)$$

$$P_{pv} = \frac{984.7}{3.6*0.75} \qquad (41)$$

$$P_{pv} = 365\ k \qquad (42)$$

Where $E_{loadTotal}$ is the total electrical energy load PSH is the Peak Sun Hour and PR is the performance ratio. The performance ratio estimated value is 75%, the Peak Sun Hours for August is 3.6 kWh and the total electrical load is 984.7 kWh. The power needed is 365 kW.

Case C: Battery Preliminary Bank sizing

The size of the batteries is calculated the result is 1931 kWh assuming that the DoD value is 40%. SF of the battery estimated value is 85% and two DoA is considered. The battery capacity is calculated using a 48V system and the result gives 40,225 Ah.

$$E_{Battery} = \frac{984.7*1}{0.85*(1-{}^{40}/_{100})} \qquad (43)$$

$$E_{Battery} = 1931\ \text{kWh} \qquad (44)$$

or

$$\text{Capacity (Ah)} = \frac{1931000}{48} \qquad (45)$$

$$\text{Capacity (Ah)} = 40{,}225\text{Ah} \qquad (46)$$

Case D: Diesel Generator model equation

The fuel consumption of the diesel generator depends on the rated power of the generator and the actual output power supplied by it. The fuel consumption of the diesel generator (FC_G) is given as:

$$FC_G = A_G \times P_G + B_G \times P_{R\text{-}G} \qquad (47)$$

Where P_G, $P_{R\text{-}G}$ are the output power and the rated power of the generator in (kW) or MW respectively, A_G and $B_G$the coefficients of the consumption curve in (l/kWh).

The fuel consumption of the diesel generator depends on the rated power of the generator and the actual output power supplied by it.

Case E: System Design and Simulation

The Hybrid Optimization Model for Electric Renewable (HOMER), is the software developed by the National Renewable Energy Laboratory (NREL). This software simulation tool is used for PV/genset /wind /hydrogen systems design and economical system size optimization. Three system configurations were simulated with HOMERtool.

(i) PV with storage only
(ii) Diesel generator only
(iii) PV-Diesel hybrid

Case F: PV Module and Inverter Selection

Maximum DC power will be generated from PV modules and delivered to the inverter if the device is activated. According to technical data of the SMA SB 5.0 (SMA Sunny PV inverter), the MPPT device will be active if inverter input DC voltage U_{PV} is between 175V and 500V.

$U_{MPPT,min}$=175V≤500V≤U_{PV}=$U_{MPPT,max}$

At a given temperature, the voltage range of the PV module can be determined in the equation (48)

$$V_{MPPT,T} = V_{MPPT,STC}\left[1 + \frac{T_{K,}P_{MMP}}{100}(T_c - 25)\right] \quad (48)$$

Where $T_{K,}P_{MMP}$ is thetemperature coefficient for voltage changing in MPPT and $V_{MPPT,STC}$ is PV module voltage in Mpp for STC.

For the module type Canadian MaxPower CS6U-340M the values are given as follows;

$T_{K,}P_{MMP}$ =-0.41%/°C and $V_{MPPT,STC}$ is 37.9V

Considering 15°C as the minimum possible ambient temperature of the location the MPP voltage V_{MPP} is given as;

$$V_{MPPT,15} = 37.9\left[1 + \frac{(-0.41)}{100} * (15 - 25)\right]V \quad \text{or} \quad (49)$$

$$V_{MPPT,15} = 39.45V \quad (50)$$

Similarlythe MPP voltage of the PV module at its maximum operating temperature (85°C) is calculated using equation (51)short circuit for STC.

For the module type Canadian MaxPower CS6U-340M, the values are given as follows;

$T_{K,}I_{SC}$ = 0.053%/°C and $I_{SC,STC}$ is 9.48V$V_{MPPT,85} = 37.9\left[1 + \frac{(-0.41)}{100} * (85 - 25)\right]V$ (51)

$$V_{MPPT,85} = 28.57V \quad (52)$$

The maximum open circuit voltage can be determined using equation (53)

$$V_{OC,T} = V_{OC}\left[1 + \frac{T_{K,}P_{OC}}{100}(T - 25)\right] \quad (53)$$

Where $T_{K,}P_{OC}$is the temperature coefficient for voltage changing in open circuit and $V_{OC,STC}$ is PV module voltage in open circuit for STC.

Taking 15°C as the minimum possible ambient temperature of the location then the maximum open circuit voltage (V_{OC}) was calculated using equation (54)

$T_{K,}P_{OC}$ =-0.31%/°C and $V_{OC,STC}$ is 46.2V

$$V_{OC,15} = 46.2\left[1 + \frac{(-0.31)}{100} * (15 - 25)\right]V \quad (54)$$

$$V_{OC,15} = 47.6V \quad (55)$$

The maximum short circuit current was calculated at the maximum operating temperature of the PV module (85°C) using equation (55)

$$I_{SC,T} = V_{MPPT,STC}\left[1 + \frac{T_{K,}I_{SC}}{100}(T - 25)\right] \quad (56)$$

Where $T_{K,}I_{SC}$ is temperature coefficient for current at short circuit and $I_{SC,STC}$ is PV module current at

$$I_{SC,T} = 9.48\left[1 + \frac{(0.053)}{100} * (85 - 25)\right]A \quad (57)$$

$$I_{SC,85} = 9.78A \quad (58)$$

Considering the parameters of the inverter and PV module, maximum number of modules per string (n_{max}) and minimum number of modules per string (n_{min}) was calculated using equations (59) and (60) respectively.

$$n_{max} = \frac{U_{MPPT,min}}{V_{MPP,85}} \quad (59)$$

Where $U_{MPPT,min}$ is the minimum input DC voltage of the inverter

$$n_{min} = \frac{175}{28.57}, = 6.1 \quad (60)$$

Similarly,

$$n_{max} = \frac{U_{MPPT,max}}{V_{MPP,15}} \quad (61)$$

Where, $U_{MPPT,max}$ is the maximum input DC voltage of the inverter.

$$n_{max} = \frac{500}{39.45} = 12.6 \quad (62)$$

n_{min}≤n≤n_{max}, (63)

Where n is the number of modules per string.

Therefore, $7 \leq n \leq 12$
Maximum string voltage was calculated with equation (64)

$$V_{oc\ \max .15} = n * V_{oc .15} \quad (64)$$

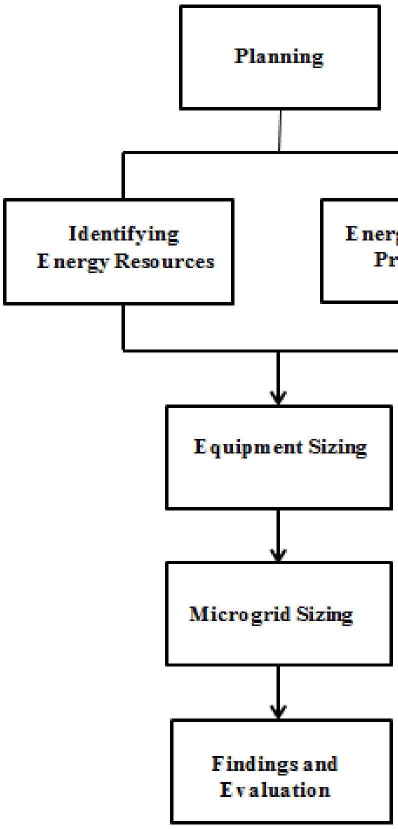

Figure 1: Systematic Block representation for Microgrid Design

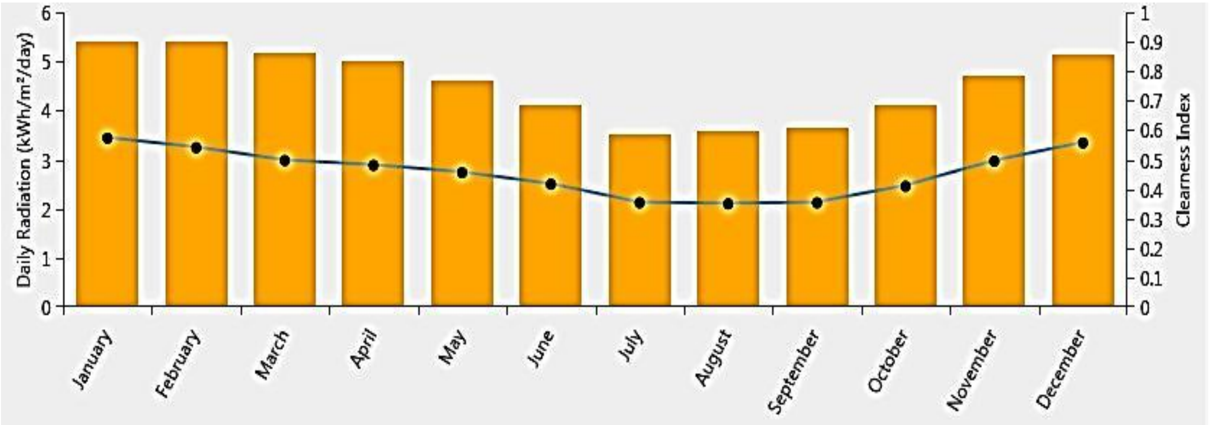

Figure 2: Illustration of solar irradiation

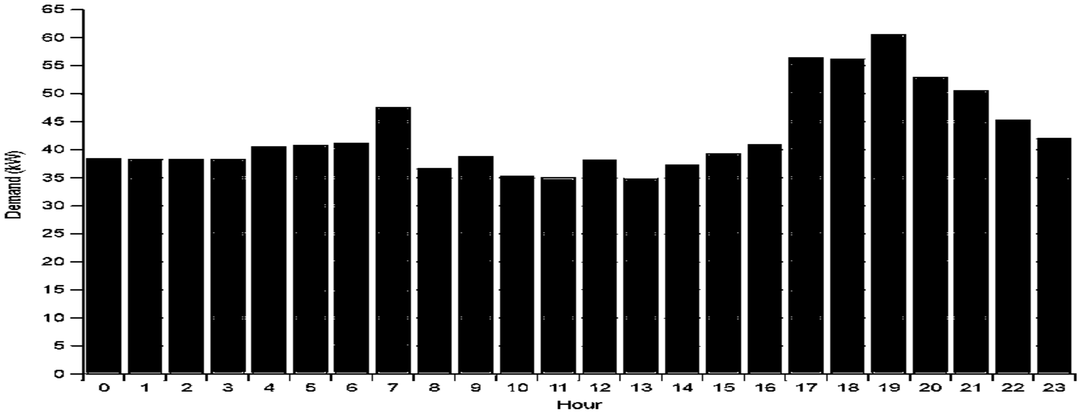

Figure 3: Consumption pattern of the community

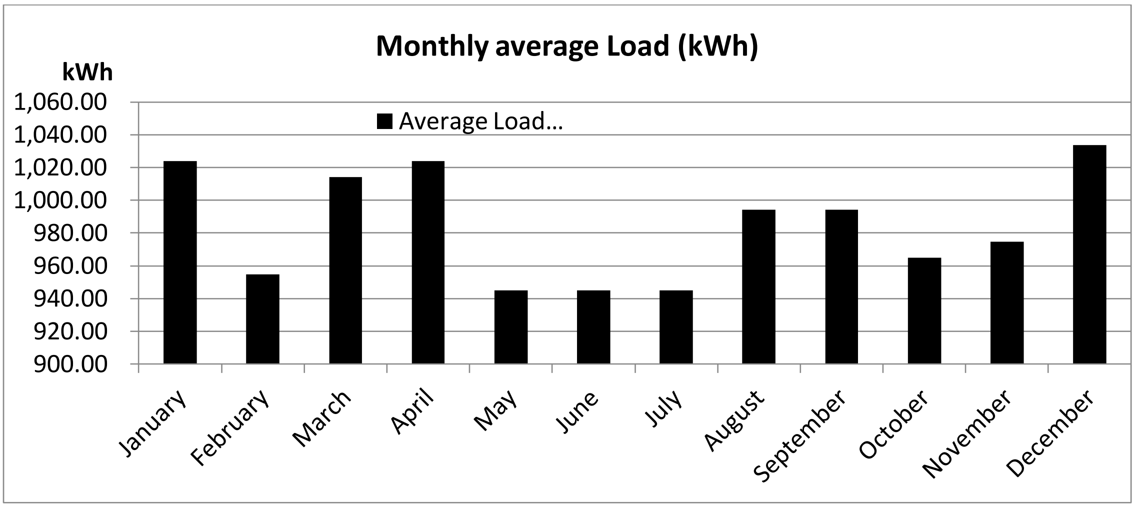

Figure 4: Monthly consumption pattern of the community

RESULTS

COE (US$)	NPC (US$)	Operating cost (US$)	Initial capital (US$)	Fuel cost (US$)	O&M (US$)	Ren Frac (%)	Total Fuel (L)	Elec Prod (kWh/yr)	CO_2 (kg/yr)
US$0.454	US$2.11M	US$158,831	US$54,400	US$110,836	US$17,870	0	110,836	359,414	290,125

Figure 5: Optimized result for Diesel Generator System

RESULTS

CS6U-340M (kW)	H3000	Converter (kW)	COE (US$)	NPC (US$)	Operating cost (US$)	Initial capital (US$)	O&M (US$)	Ren Frac (%)	Elec Prod (kWh/yr)	CO_2 (kg/yr)
365	4,104	306	US$1.25	US$5.82M	US$53,430	US$5.13M	US$0.00	100	474,083	0

Figure 6: Optimized PV-Battery System.

RESULTS

CS6U-340M (kW)	H3000	Converter (kW)	COE (US$)	NPC (US$)	Operating cost (US$)	Initial capital (US$)	O&M (US$)	Ren Frac (%)	Total Fuel (L)	Elec Prod (kWh/yr)	CO_2 (kg/yr)
365	240	105	US$0.274	US$1.27M	US$34,118	US$832,676	US$3,036	86.6	15,563	435,919	40,738

Figure 7: Optimized result for PV-Diesel Hybrid system

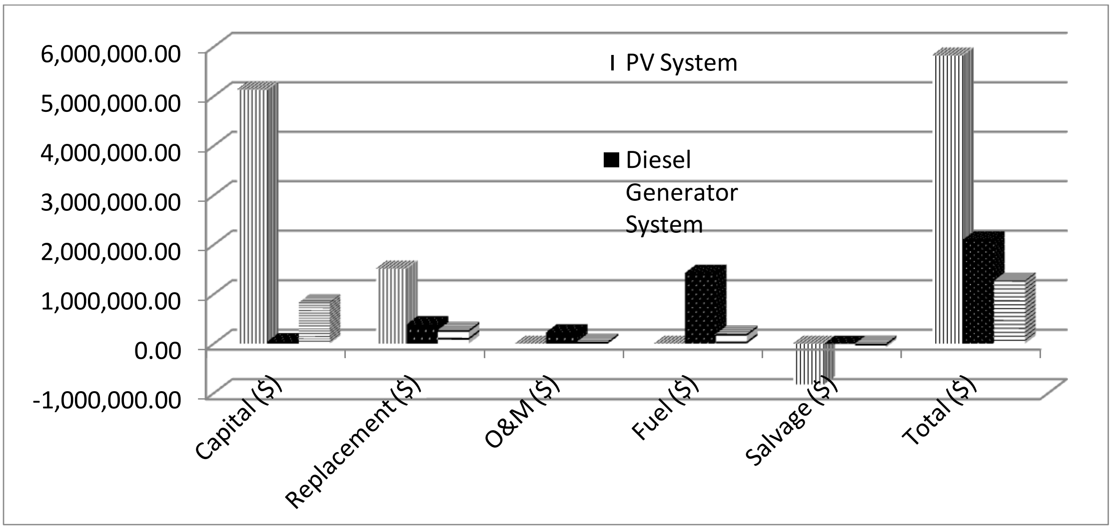

Figure 8: System cost comparison

Table 1: Solar Irradiation adopted from NASA database Online, accessed on 6/6/201

Month	Clearness Index	Solar Radiation (kWh/m^2/day)
Jan	0.6	5.4
Feb	0.5	5.4
Mar	0.7	5.2
Apr	0.5	5.0
May	0.5	4.6
Jun	0.4	4.1
Jul	0.4	3.5
Aug	0.3	3.6
Sep	0.4	3.7
Oct	0.4	4.1
Nov	0.5	4.7
Dec	0.6	5.1
Year Average		**4.53**

Table 2: Ambient Temperature

Month	Average low temperature (^{0}C)	Average low temperature (^{0}C)	Average low temperature (^{0}C)
JAN	21	32	26.5
FEB	23	33	28.0
MAR	23	33	28.0
APR	23	32	27.5
MAY	23	31	27.0
JUN	23	30	26.5
JUL	22	30	26.0
AUG	22	29	25.5
SEP	22	29	25.5
OCT	22	30	26.0
NOV	22	31	26.5
DEC	21	32	26.5

Table 3: Load profile data

Hour of Day	Load Power (W)	Load Design Margin + 30% (W)	Design Load Power (W)
00	28,454	8,536	36,990
01	28,334	8,500	36,834
02	28,334	8,500	36,834
03	28,334	8,500	36,834
04	30,019	9,006	39,025
05	30,161	9,048	39,209
06	30,475	9,143	39,618
07	35,136	10,541	45,677
08	27,125	8,138	35,263
09	28,680	8,604	37,284
10	26,140	7,842	33,982
11	25,890	7,767	33,657
12	28,260	8,478	36,738
13	25,760	7,728	33,488
14	27,610	8,283	35,893
15	29,040	8,712	37,752
16	30,295	9,089	39,384
17	41,765	12,530	54,295
18	41,584	12,475	54,059
19	44,775	13,433	58,208
20	39,143	11,743	50,886
21	37,364	11,209	48,573
22	33,496	10,049	43,545
23	31,097	9,329	40,426
Total	757,271		984,452

Table 4: Community Average Load Consumption over 24 Hour

Month / Hour	January	February	March	April	May	June	July	August	Septem-ber	Octo-ber	Novem-ber	Dece-mber
00	38.5	35.9	38.1	38.5	35.5	35.5	35.5	37.4	37.4	36.3	36.6	38.8
01	38.3	35.7	37.9	38.3	35.4	35.4	35.4	37.2	37.2	36.1	36.5	38.7
02	38.3	35.7	37.9	38.3	35.4	35.4	35.4	37.2	37.2	36.1	36.5	38.7
03	38.3	35.7	37.9	38.3	35.4	35.4	35.4	37.2	37.2	36.1	36.5	38.7
04	40.6	37.9	40.2	40.6	37.5	37.5	37.5	39.4	39.4	38.2	38.6	41.0
05	40.8	38.0	40.4	40.8	37.6	37.6	37.6	39.6	39.6	38.4	38.8	41.2
06	41.2	38.4	40.8	41.2	38.0	38.0	38.0	40.0	40.0	38.8	39.2	41.6
07	47.5	44.3	47.0	47.5	43.8	43.8	43.8	46.1	46.1	44.8	45.2	48.0
08	36.7	34.2	36.3	36.7	33.9	33.9	33.9	35.6	35.6	34.6	34.9	37.0
09	38.8	36.2	38.4	38.8	35.8	35.8	35.8	37.7	37.7	36.5	36.9	39.1
10	35.3	33.0	35.0	35.3	32.6	32.6	32.6	34.3	34.3	33.3	33.6	35.7
11	35.0	32.6	34.7	35.0	32.3	32.3	32.3	34.0	34.0	33.0	33.3	35.3
12	38.2	35.6	37.8	38.2	35.3	35.3	35.3	37.1	37.1	36.0	36.4	38.6
13	34.8	32.5	34.5	34.8	32.1	32.1	32.1	33.8	33.8	32.8	33.2	35.2

14	37.3	34.8	37.0	37.3	34.5	34.5	34.5	36.3	36.3	35.2	35.5	37.7
15	39.3	36.6	38.9	39.3	36.2	36.2	36.2	38.1	38.1	37.0	37.4	39.6
16	41.0	38.2	40.6	41.0	37.8	37.8	37.8	39.8	39.8	38.6	39.0	41.4
17	56.5	52.7	55.9	56.5	52.1	52.1	52.1	54.8	54.8	53.2	53.8	57.0
18	56.2	52.4	55.7	56.2	51.9	51.9	51.9	54.6	54.6	53.0	53.5	56.8
19	60.5	56.5	60.0	60.5	55.9	55.9	55.9	58.8	58.8	57.0	57.6	**61.1**
20	52.9	49.4	52.4	52.9	48.9	48.9	48.9	51.4	51.4	49.9	50.4	53.4
21	50.5	47.1	50.0	50.5	46.6	46.6	46.6	49.1	49.1	47.6	48.1	51.0
22	45.3	42.2	44.9	45.3	41.8	41.8	41.8	44.0	44.0	42.7	43.1	45.7
23	42.0	39.2	41.6	42.0	38.8	38.8	38.8	40.8	40.8	39.6	40.0	42.4
TOTAL	**1024**	**955**	**1014**	**1024**	**945**	**945**	**945**	**994**	**994**	**965**	**977**	**1034**

Table 5:Average daily load to PSH ratio data

Month	PSH (KWh)	Average daily load (KWh)	Ratio (Average daily load/PSH)
January	5.4	1024	190
February	5.4	955	177
March	5.2	1014	195
April	5	1024	205
May	4.6	945	205
June	4.1	945	231
July	3.5	945	270
August	**3.6**	**994**	**276**
September	3.7	994	269
October	4.1	965	235
November	4.7	975	207
December	5.1	1034	203

Table 6: Photovoltaic Module Characteristics

S/N	Canadian MaxPower CS6U-340M	
1	Nominal Power	340Wp
2	Optimal Operating Voltage (V_{mpp})	37.9V
3	Current (I_{mpp})	8.97A
4	Open Circuit Voltage (V_{oc})	46.2V
5	Short Circuit Voltage (I_{SC})	9.48A
6	Efficiency	17.49%
7	Operating Temperature	-40^0 C - 85^0 C
8	Maximum Series Fuse	15A
9	Temperature Coefficient of - P_{mpp} (T_k, P_{mpp})	-0.41%/^{0} C
10	Temperature Coefficient of V_{oc} (T_k, V_{oc})	-0.31%/^{0} C
11	Temperature Coefficient of - I_{SC} (T_k,I_{sc})	0.053%/^{0} C

Table 7: Photovoltaic Inverter Characteristics

S/N	Photovoltaic Inverter Characteristics		
1	Inverter Type	Sunny Boy SB5.0	
2	Inverter efficiency	98%	
3	Maximum input voltage	600V	
4	MPP Voltage range	175V-500V	
5	Maximum input current	15A	
6	PV inverter size	5KW	
7	Lifetime	15 years	
8	No of independent MPP input	2	
9	String length	11	
10	String per MPP input A	11	
11	String per MPP input B	11	
12	Total number of modules per 5KW inverter	22	
	Inverter details	**Input A**	**Input B**
13	Module count	11	11
14	Maximum input voltage, V_{oc} at 15^0 C	524V	524V
15	Minimum input voltage V_{mpp} at 85^0 C	313V	313V
16	Maximum input current	15A	15A
17	String input current	9.78A	9.78A

Table 8: Battery Characteristics

ii S/N	Battery Characteristics	
1	Battery type	Hoppecke 24 OPzS 3000
2	No of battery in a string	24
3	Battery voltage	48V
4	Battery rating	3000Ah
5	Battery loss during charging and discharging	29,666kWh/yr
6	Storage depletion	688 kWh/yr
7	Cost of each battery	$1,100
8	Autonomy	1 days
9	Dept. of discharge	40%
10	Charging voltage	2.35V
11	Battery usable energy	1,029 kWh/day

Table 9: Emissions of Environmental Analysis

	Emission (Kg/year)					
System Description	**Carbon Dioxide**	**Carbon Monoxide**	**Unburned Hydrocarbons**	**Particulate Matter**	**Sulfur Dioxide**	**Nitrogen Oxides**
PV-Battery	0	0	0	0	0	0
Diesel Generator Only	290,125	1,829	80	11	710	1,718
PV-Diesel Hybrid	40,738	257	11	2	100	241

Case G: Wind Speed Data for turbine generation
The daily speed data used in this study was obtained from the meteorological station of International Institute of Tropical Agriculture (IITA), (Latitudes$7.43^o N$, $Longitude$ $3.9^o E$; $Altitude$ $227.2m$).

Case H:Computation of Weibull Parameters of Wind Speedfor turbine generation
Modellingof wind speed variation, the Weibull two-parameter (shape parameter k and scale parameter c) functions. The probability density function of the Weibull distribution are presented as;

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{65}$$

Where $f(v)$ is the probability of observing wind speed v, k is the dimensionless Weibull shape parameter and c is the Weibull scale parameter.
The corresponding cumulative probability function of the Weibull distribution is given as

$$F(v) = 1 - exp\left[-\left(\frac{k}{c}\right)^{k}\right] \tag{66}$$

Where $F(v)$ is the cumulative probability function of observing wind speed v.
The evaluation of the shape (k) and scale (c) parameters in the Weibull distribution function requires a good fit of Equation (67) to the recorded discrete cumulative frequency distribution gives as:

$$In\{-In[1 - F(v)]\} = kIn\,(v) - k\,In\,c \tag{67}$$

Therefore, a plot of $In\{-In[1 - F(v)]\}$ versus $In(v)$ gives a straight line, the gradient of the line is k and the intercept with the y axis is $-k\,In\,c$ the k values range from 1.5 – 1.0 for most wind conditions[7]. The mean values of the wind speed v_m can be defined in terms of the Weibull parameters k and c as;

$$v_m = c\mathcal{T}\left(1 + \frac{1}{k}\right) \tag{68}$$

Where $v_m$is the mean value of the wind speed and $\mathcal{T}(\ )$ is the gamma function of ( ).

Case I: Estimation of Wind Power Density for Turbine Power Generation
The available power in the wind flowing at mean speed v_m though a wind rotor blade with sweep area A at any given site can be estimated as[7,8];

$$P(v) = \frac{1}{2}\rho A v_m{}^{3} \tag{69}$$

The wind power density (wind power per unit area) based on the Weibull probability density function can be calculated as;

$$p(v) = \frac{\rho(v)}{A} = \frac{1}{2}\rho c^3\left(1 + \frac{3}{k}\right) \tag{70}$$

Where $P(v)$ is the wind power (W), $P(v)$ is the wind power density $(W/m^2), \rho$ is the air density at the site $= 1.21\left(\frac{kg}{m^3}\right)$, A is the swept area of the rotor blades $(m^2), v_m$ is the wind speed at that location (m/s).

Case J: Prediction Performance of the Weibull Distribution Model
The prediction accuracy of the model in the estimation of the wind speeds with respect to the actual values were evaluated based on the correlation coefficient, R^2, root mean square error (RMSE), and coefficient of efficiency (COE). These parameters were calculated based on the following equations:

$$R^2 = \frac{\sum_{i=1}^{N}(y_i - z)^2 - \sum_{i=1}^{N}(x_i - z)^2}{\sum_{i=1}^{N}(y_i - z)^2} \tag{71}$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(y_i - x_i)^2\right]^{1/2} \tag{72}$$

$$COE = \frac{\sum_{i=1}^{N}(y_i - x_i)^2}{\sum_{i=1}^{N}(y_i - z)^2} \tag{73}$$

$y_i$is the1^{th} actual data, x_i is the 1^{th}predicted data with the Weibull distribution, z is the mean of actual data, N is the number of observations.

3.2 Computation of the characterised reliability-index and three parameter weilbull distribution
Case K:The Mean time to failure of the three-parameter weilbull distribution (MTTF) is given as:

$$\text{MTTF} = \gamma + \eta\ \Gamma\left(1 + \frac{1}{\beta}\right) \tag{74}$$

where;

$$\left.\begin{array}{l} \gamma \geq 0 \text{ and} t,\ \beta,\ \eta > 0 \\ \Gamma(x) = \int_0^\infty e^{-x} x^{n-1} \end{array}\right\} \tag{75}$$

η : Scale parameter
$\Gamma(x)$: Gamma Function

γ : Location parameter

β : shape parameter

t : Time

The term (MTTF) is applied to non-repairable points which operate under specified condition.

Case L: Mean time between failure (MTBF)

This is the term which is applied to repairable terms, which measure the average time that a particular equipment will fail and remain in service. MTBF of an equipment may be reduced to potential defects introduced by poor maintenance procedures.

Thus,

$$\text{MTBF} = \frac{1}{n}\sum_{i=1}^{n}\left(t_k \dots t_{k-1}\right) = \frac{t_n - t_o}{n} = \frac{t_n}{n} \tag{77}$$

Since, t_0 = 0 at the beginning.

$$\text{Then, MTBF} = \frac{\text{Total operating time}}{\text{No. of failures in that time}} \tag{78}$$

Case 1: Availability performance

Availability performance is the ability of an item to be in a state to perform a required function under a given conditions that is for a given instance of time or over a given time interval this mean that;

(i) All items assumed operating conditions unless failed scenario.

(ii) The exception would have been standby redundancy but this scarcelyexists power station because of high power supply demand.

(iii) The outcomes in the analysis are based on two fundamental rules for combining probabilities.

(iv) If A and B are two independent events with probabilities $\rho(A)$ and $\rho(B)$ of occurring, then the probability $\rho(AB)$ that both events will occurs is the product;

$$\rho(AB) = \rho(A).\rho(B) \tag{79}$$

(v) Similarly, if two events A and B are mutually exclusive so that when one occurs the other cannot occur, the probability that either A or B will occur is :

$$p(A\ B) = p(A) + p(B) \tag{80}$$

Case 2: Failure rate

Failure may be either partial or complete, gradual or sudden it may be caused by inherent weaknesses or misuse. Therefore, failure-rate is related to both number of failures per unit time that is the number of items which fails in a given time depends not only on the quality of the item, Hence;

(i) If the number of components in operation at the time of failure is Nr

Then failure –rate $\lambda(t)$ is given as;

$$\lambda(t) = \lim_{\Delta t \to \infty} \frac{1}{N_s} \times \frac{\Delta N_f}{\Delta_t} = \frac{1}{N_s} \times \frac{\delta N_f}{\delta t} \tag{81}$$

Case 3: Operational availability

The operational availability (A_0) given as;

$$A_o = \frac{Up - Time}{Operating - Time} \tag{82}$$

Thus,

Availability,

$$(A_V) = \frac{Available\ \ Hour}{Period\ \ Hour} \times \frac{100}{1} \tag{83}$$

Available Hours = period Hours- forced outages hours – scheduled outages hours.

Essentially, available performance is defined and considered in four (4) different form measurement as: Availability function limiting availability, average availability etc.

All these measurement are based on the function *x(t)*, which denotes the status of a repairable system, at time *(t)*. The instant availability at time *(t)* or point availability is given as[9]:

$$A(t) = \rho(x)(t) = 1 \tag{84}$$

This is the probability that the system is operational at time (t) which is defined as;

$$A = \text{limit} \quad t \to \infty A(t) \tag{85}$$

This quantity is the probability that the systems will be available after it has run for a long time and is a significant measurement of the performance of a repairable system given as;

$$R(t) = \ell^{-\left(\frac{t-\gamma}{\eta}\right)^{\beta}}, \; t \geq \gamma \tag{86}$$

Case 4:Reliability function of the three (3) – parameter weilbull distribution

The three –parameters weilbull failure rate function given as;

$$\lambda(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1}, \; t \geq \gamma \tag{87}$$

Case 5: Weilbull shape parameter(β)

The weilbull shape parameter (β) is also known as the weilbull slope. This is because the value of β is equal to the slope of a line in a probability plot.

(i) When the shape parameter , β < 1 (this means that the failure rate decreases)

(ii) When the shape parameter, β = 1 (this means that failure-rate is constant with time (t) and the distribution is equal to the exponential distribution)

(iii) When the shape parameter, β > 1 (this means that failure rate increases)

Case 6: Weilbull scale parameter, η

That is increasing the value ofη while keeping β constant has the effects of stretching out the probability density function (pdf). A change in the scale parameter (η) has the same effect on the distribution as a change of the abscissa scale. Since the area under a pdf curve is a constant value, the peak of the pdf curves will also decreases with increase of η [10].

Case 7: Weilbull Location Parameter, γ

The location parameter, γ actually accounts for the subtraction (positive or negative) value that places the points in an acceptable straight line. Changing the value of the location parameter γ , has the effects of pushing the distribution and associated function if (γ> 0) or to the left if (γ< 0).

Case 8: Prediction Performance of Weilbull Distribution Model

The prediction accuracy of the model in the estimation of the turbine-blade failures with respect to actual values were evaluated based on the correlation coefficient R^2, root mean square error (RMSE) and coefficient of efficiency (COE) [11]. These parameters are calculated based on the following equation as;

$$R^2 = \frac{\sum_{i=1}^{N}(y_i - z)^2 - \sum_{i=1}^{N}(x_i - z)^2}{\sum_{i=1}^{N}(y_i - z)^2} \tag{88}$$

Similarly, the root mean square error (RMSE) given as;

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(y_i - x_i)^2\right]^{1/2} \tag{89}$$

The coefficient of efficiency (COE) given as;

$$COE = \frac{\sum_{i=1}^{N}(y_i - x_i)^2}{\sum_{i=1}^{N}(y_i - z)^2} \tag{90}$$

where y_i is the i^{th} actual data X_i is the i^{th} predicted data with the weilbull distribution (z) is the mean of the actual data, N is the number of observations.

The life or scale parameter (α) can be determined given as;

$$\alpha = \ell^{-\left[\frac{c}{m}\right]} \tag{91}$$

(i) By the estimation of two-parameters technique for the prediction if the system behavior of the component are according to the equipment – curve distribution.

(ii) Weilbull probability distribution function f(t) shows probability of failure in certain time (t) given as;

$$F(t) = \left(\frac{\beta}{\alpha}\right)\left(\frac{t}{\alpha}\right)^{\beta-1} \ell^{-\left(\frac{t}{\alpha}\right)^{\beta}} \; ; \; for \begin{cases} \alpha > 0 \\ \beta > 0 \\ 0 \le t <= \infty \end{cases} \tag{92}$$

(iii) The cumulative distribution function F(t), which shows the probability of failure in time (t) would be calculated as;

$$F(t) = 1 - \ell^{-\frac{t}{\alpha}^{\beta}} \; ; \; for \begin{cases} \alpha > 0 \\ \beta > 0 \\ 0 \le t <= \infty \end{cases} \tag{93}$$

Essentially, reliability function R(t) which shows probability of remaining intact till the time (t) and the rates of failure λ(t) which can be expressed as;

$$R(t) = 1 - F(t) = \ell - \left(\frac{t}{\alpha}\right)^{\beta} \quad or \tag{94}$$

$$\lambda(t) = \frac{F(t)}{R(t)} = \left(\frac{\beta}{\alpha}\right)\left(\frac{t}{\alpha}\right)^{\beta-1} \tag{95}$$

From observation, the shape –parameter (β) affects the shape distribution curve that is when the shape parameter changed, the curve f(t) varies differently in shape. For example if the curve turns to exponential distribution while β = 1

(i) That is the failure rate will be decreasing while β<1, means that the component is in the early failure state.

(ii) Similarly, when failure rate is constant while, β=1, the components is in the occasional failure condition. Incidentally, the failure rate is increasing while β>1 this means that the component is in the loss failure condition [12].

Case 9: The Mean and standard deviation of a weilbull distribution evaluation

The mean and standard deviations are presented in terms of shape and scale –parameter given as:

$$\mu = \mu\Gamma\left(1 + \frac{1}{\beta}\right) \tag{96}$$

and

$$\delta^2 = \alpha^2\left[\Gamma\left(1 + \frac{2}{\beta}\right) - \Gamma^2\left(1 + \frac{1}{\beta}\right)\right] \tag{97}$$

where;

$\Gamma(\cdot)$ represents the gamma function which could be estimated in the following form as:

$$\Gamma = \sqrt{2\pi t}^{(t-0.5)}\ell^{-t}\left(1 + \frac{1}{12t}\right) \tag{98}$$

(i) In the consideration for long term unavailability without considering restriction related to repair or replacement time of equipment in order to estimate equipment failure-rate, the Meantime to failure (MTTF) and the mean time between failure (MTBF) should be equal.

Therefore, $\text{MTBF} = \alpha\,\Gamma\left(1 + \frac{1}{\beta}\right)$ (99)

While, the total failure-rate for turbine–blade are considered as an important components for reliable performance given as:

$$\lambda(t) = \sum_{i=1}^{N} \lambda_i(t)$$

(100)

Where, $\lambda_i(t)$ is the rate of failure in i-th critical part of equipment and n is the total subcomponents of the turbine-blades under observations [13]

IV. RESULTS AND DISCUSSION

$n_1(plan\ \ 1) = \text{Total}\ \ \text{cost}\ = $ ₦817650340800

$n_2(plan\ \ 2) = \text{Total}\ \ \text{cost}\ = $ ₦765426724800

$n_3(plan\ \ 3) = \text{Total}\ \ \text{cost}\ = $ ₦749953060800

$n_4(plan\ \ 4) = \text{Total}\ \ \text{cost}\ = $ ₦746084644800

$n_5(plan\ \ 5) = \text{Total}\ \ \text{cost}\ = $ ₦520609583900

Since, $n_1 > n_2 > n_3 > n_4 > n_5$, then,

$n_1 - n_2 = $ ₦5222361600

$n_2 - n_3 = $ ₦154736640000

$n_3 - n_4 = $ ₦3,868,416,000

$n_4 - n_5 = $ ₦225474060900

$$n_1 - n_5 = (n_1 + n_2) + (n_2 + n_3) + (n_3 + n_4) + (n_4 + n_5)$$

or

$n_1 - n_5 = $ ₦297040756900

Case 10

$$(\%\ \ saving\ ) = \frac{n_1 - n_2}{n_1 - n_5} \times 100\ \%$$

$$= \frac{5222361600\quad 0}{2970407569\quad 00} \times 100\ \%$$

$$= 17.58129643\ \% \approx 17.58\ \%$$

Case 11

$$(\%\ \ saving\ ) = \frac{n_2 - n_3}{n_1 - n_5} . \times 100\ \%$$

$$= \frac{1547366400\quad 0}{2970407569\quad 00} \times 100\ \%$$

$$= 5.209273017\ \% \approx 5.21\ \%$$

Case 12

$$(\%\ \ saving\ ) = \frac{n_3 - n_4}{n_1 - n_5} . \times 100\ \%$$

$$= \frac{3868416000}{2970407569\quad 00} \times 100\ \%$$

$$= 1.302318254\ \% \approx 1.30\ \%$$

Case 13:

$$(\%\ \ saving\ ) = \frac{n_4 - n_5}{n_1 - n_5} . \times 100\ \%$$

$$= \frac{2254750609\quad 00}{2970407569\quad 00} \times 100\ \%$$

$$= 75.90711229\ \% \approx 75.91\ \%$$

Case 14:

$Total \quad saving \quad (n_1 - n_5). = ₦5222361600 \quad 0 + 1547366400 \quad 0 + \quad ₦3868416000 \quad + ₦2254750609 \quad 00$
= ₦2970407569000

Check (percentage saving):

$$17.58\% + 5.21\% + 1.30\% + 75.91\% = 100\%$$

Table 10:Cost of optimal expansion plans for twenty-year look-ahead periods with optimization strategy with plans($n_1 - n_5$)

Different optimization plans (n)	Capacity (MW) (MW) pg_1	combination (MW) pg_2	(MW) pg_3	No. of units			Total cost (₦) (n), C_T=n = $C_1+C_2+C_3$ (₦)
n_1 = plan 1	200 MW	250 MW	300 MW	U_1 =1	U_2 = 7	U_3 =1	₦817,650,340,800
n_2 = plan 2	200 MW	250 MW	300 MW	U_1 =7	U_2 = 1	U_3 =2	₦765,426,724,800
n_3 = plan 3	200 MW	250 MW	300 MW	U_1 =4	U_2 = 1	U_3 =4	₦749,953,060,800
n_4 = plan 4	200 MW	250 MW	300 MW	U_1 =2	U_2 = 5	U_3 =2	₦746,084,644,800
N_5 = plan 5	200 MW	250 MW	300 MW	U_1 =3	U_2 = 3	U_3 =3	₦520,609,583,900

Table 11: Capacity and Cost Ranking Processes

S/No	**Ranked (MW) according to capacity**	**Rank (R_1) capacity**	**Ranked according to cost (₦)**	**Ranked (R_2) R-Cost**	**d=R_1-R_2**	**d^2**
1.	U_1 = 1×200= 200	1	692,778	1.5	–0.5	+0.25
	U_2 = 7×250= 1750	15	3,174,638	15.5	–0.5	+0.25
	U_3 = 1×300= 300	3	799,538	3.5	–0.5	+0.25
2.	U_1 = 7×200= 1400	11.5	2,459,658	11	+0.5	+0.25
	U_2 = 1×250= 250	2	745,238	2.5	–0.5	+0.25
	U_3 = 2×300= 600	5	1,163,978	4.5	+0.5	+0.25
3.	U_1 = 4×200= 800	7	1,443,738	7.5	–0.5	+0.25
	U_2 = 1×250= 250	2	745,238	2.5	–0.5	+0.25
	U_3 = 4×300= 1200	9.5	2,091,578	9.0	+0.5	+0.25
4.	U_1 = 2×200= 400	4.5	913,658	4.0	+0.5	+0.25
	U_2 = 5×250= 1250	11	2,180,838	11.5	–0.5	+0.25
	U_3 = 2×300= 600	5	1,163,978	4.5	+0.5	+0.25
5.	U_1 = 3×200=600	5	1,163,978	4.5	+0.5	+0.25
	U_2 = 3×250= 750	6.5	1,371,038	6.0	+0.5	+0.25
	U_3 = 3×300= 900	8.5	1,594,658	8.5	0	0
		$\Sigma R_1 = 96.5$		$\Sigma R_2 = 96.5$	$\Sigma d = 0$	$\Sigma d^2 = 3.5$

Using spearman correlation coefficient relationship given as:

$$r_k = 1 - \frac{6\Sigma d^2}{n^2 - n} = 1\frac{6\Sigma d^2}{n(n^2 - 1)}$$

Substitute the numerical values into the equation(26)as:

$$r_k = 1 - \frac{6\Sigma d_i^2}{n(n^2 - n)}$$

$$r_k = 1 - \frac{6 \times 3.5}{15(15^2 - 1)}$$

$$r_k = 1 - \frac{21}{15\,(225 \quad - 1)}$$

$$r_k = 1 - \frac{21}{15 \times 224} = 1 - \frac{21}{3360}$$

$$r_k = 1 - \frac{21}{3360}$$

$$r_k = 1 - 0.00625$$

$$r_k = 0.99375$$

$$r_k \approx +1$$

V. CONCLUSION

This paper presented an energy-mix dynamic for optimization of power generation strategy and expansion in a developing economic growth. The techniques is highly flexible and proffer fast solution to problems and developed five optimization plans in terms of mix-capacity combination for the selection of some generating station in Nigeria in order to search for the best capacity combination option with respect to cost in order to derive financial benefits and cost-serving. This paper formulated decomposition technique which is used to analyse the breaking down processes of capacity combination in order to provide for an optimization search with the aim of deriving financial objectives through cost-function. This study strongly rely on the analysis of load demand on the view to determine the capacity of energy generation at different generating station, particularly in Nigeria.

Energy-mix dynamic for optimization of power generation strategy and expansion hold significant role in the future activities of every given nation for purpose of regular power supply for effective and efficient micro and macro-economic activities.

Therefore, it is observed that generating capacity for a given generating station, must regularly be check for purpose of matching capacity generation and energy demand equilibrium at the receiving –end (consumers). That is mismatches as a result of violation, contingencies etc between generation of power and energy demand scenario may seriously led to system collapse. Hence, integration of mixed capacity combination set of generating unit will provide optimal options for cost saving for purpose of deriving financial benefits.

The activities and performances of solar system configurations were examined for the projected life of25 years. The results showed that PV Battery system has 100% renewable penetrationwith no emission which made it environmentally friendly than other systems but it required that large battery bank which made it most expensive system with highest NPC and COE. Diesel generator recorded the highest emission into the environment and increase greenhouse effect and global warming. It is also identified with highest fuel consumption. The systems described andconsidered relatively higher cost compared to PV-Diesel hybrid system. However, the PV-Diesel hybrid system had 86.6% PV penetration and more benefit of cost saving, emission reduction of about without compromising reliability.

The actual mean yearly wind speed of 2.748 m/s for Kwara State which shows a low wind speed region.

The yearly wind power density value of 12.555 wm^{-2} for the whole year indicates that Kwara State belongs to wind power class, since the density values is less than 100 Wm^{-2}.

The daily measured time series wind speed data for the study case in some selected area in Nigeria have been analyzed statistically based on Weibull probability distribution function. The daily, monthly, seasonal and yearly Weibull probability distribution parameters, mean wind speeds and wind energy density availability have been determined.

NOMENCLATURE

$f(v)$	Probability of overserving wind speed v,
k	dimensionless Weibull shape factor
c	Weibull scale parameter
$F(v)$	Cumulative distribution function of observing wind speed v,
v	wind speed (m/s)
v_m	mean value of the wind speed
$\mathcal{T}(x)$	gamma function of (x)

$P(v)$	wind power (W)
$p(v)$	wind power density Wm^{-2}
ρ	air density at the site = $1.21(kg/m^2)$
A	swept area of the rotor blades (m^2)
R^2	correlation coefficient
$RMSE$	root mean square error
COE	coefficient of efficiency
y_i	1^{th}actual wind speed data (m/s)
x_i	1^{th}predicted wind speed data with the Weibull distribution (m/s)
z	mean of actual wind speed data (m/s)
N	number of observations
δ	standard deviation

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Appendix A_1

Selected Windy State and Capacity

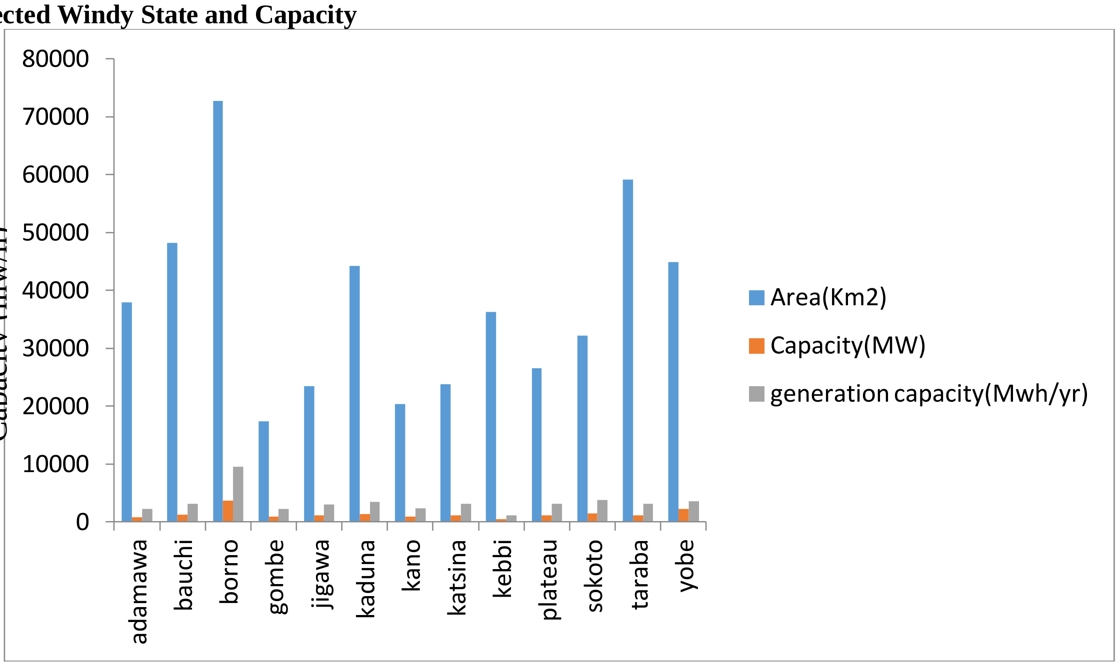

Table 12: Windy Selected States

Selected windy states	Area(Km2)	Capacity(MW)	Generation capacity(Mwh/yr)
Adamawa	37957	854	2244
Bauchi	48197	1204	3166
Borno	72767	3638	9561
Gombe	17428	871	2290
jigawa	23415	1170	3070
Kaduna	44217	1326	3486
Kano	20389	917	2411
Katsina	23822	1191	3130
Kebbi	36320	454	1193
Plateau	26539	1194	3138
Sokoto	32146	1446	3801
Taraba	59180	1183	3110
Yobe	44880	2244	3539

Appendix A_2
Gas turbine blade power plant

Plate 1: Gas turbine plant

Plate 2: Gas turbine plant/combine cycle

Appendix A_3
Design and Install Solar PV System

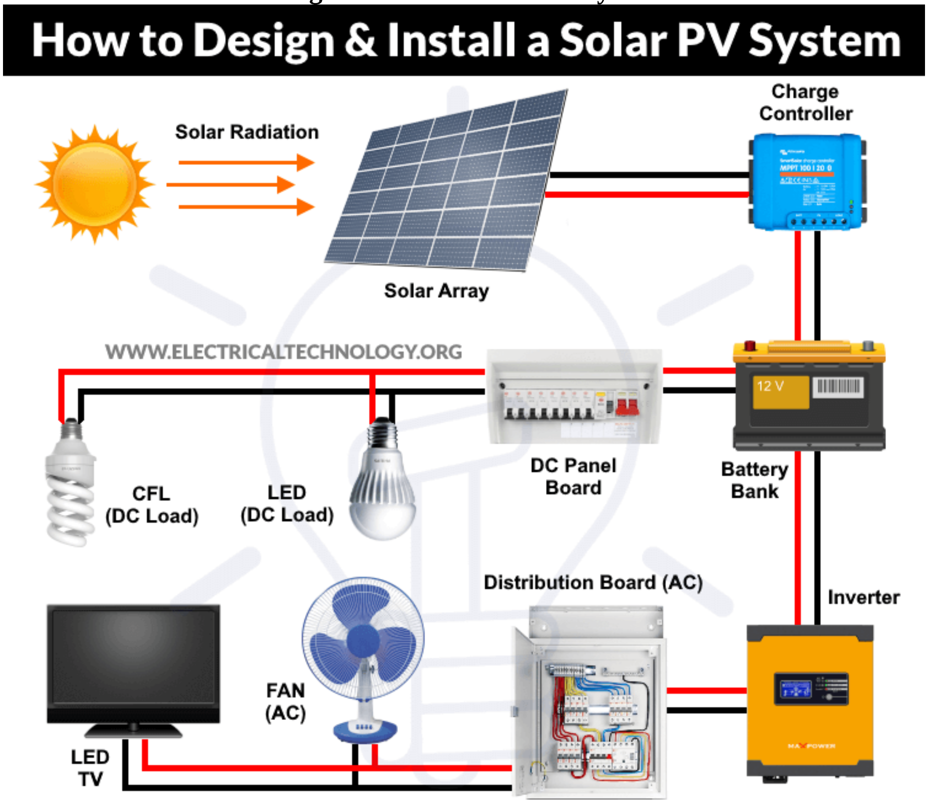

Plate 3: PV/Solar System Renewable Sources

Plate 4: PV/solar Panel for different energy capacity

Appendix A_4
Wind Turbine power plant

Plate 5: Increasing capacity of wind turbine generation

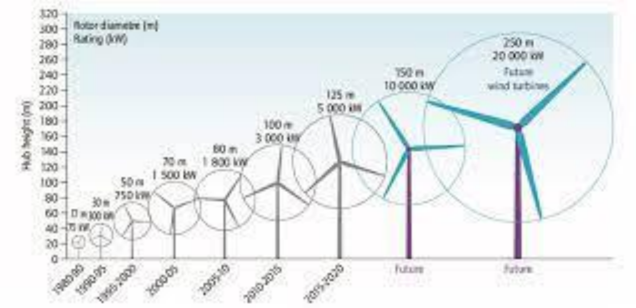

Plate 6: Wind turbine generator capacity

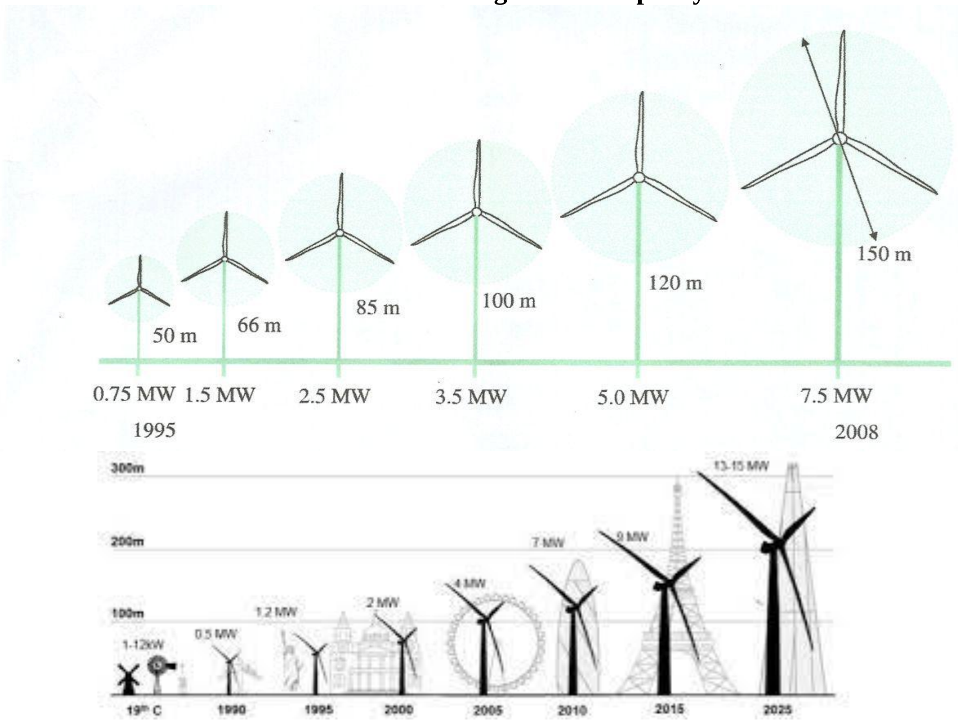

Plate 7: Wind turbine generator (WTG) with different height (m)

Appendix A_5
Renewable Energy

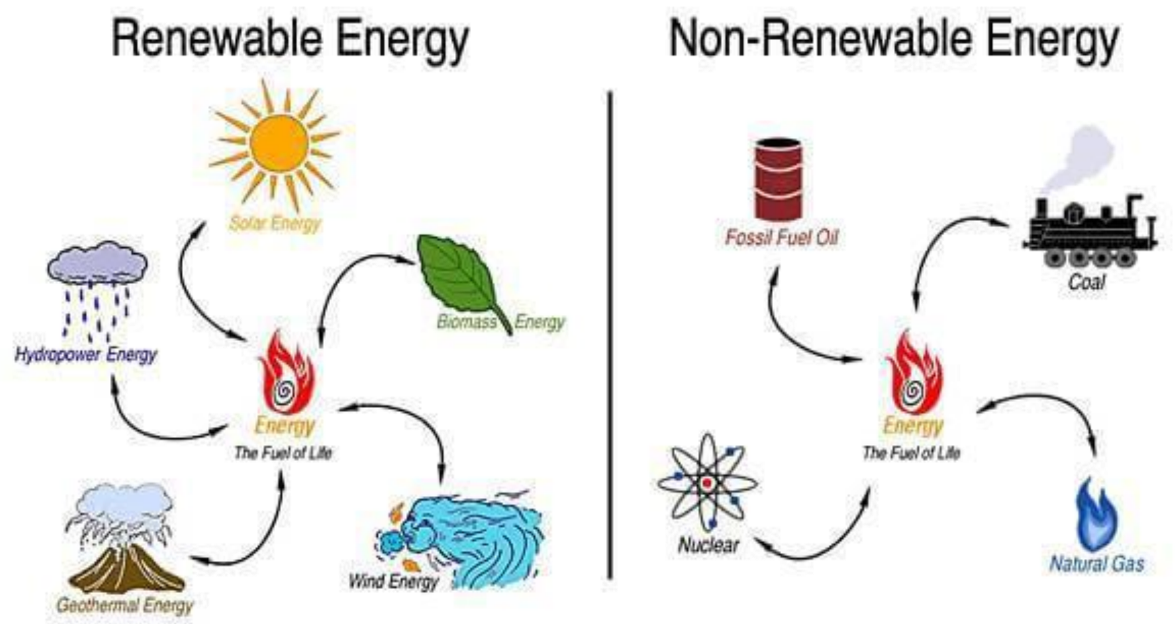

Plate 8: Renewable and non-renewable energy sources

AppendixA_6
Program C++ Simulation

E:\CAPACITY COMBINATION\Braid c++ 254 MW,.cpp - Dev-C++ 5.11

File Edit Search View Project Execute Tools AStyle Window Help

TDM-GCC 4.9.2 64-bit Release

(globals)

Project Classes Debug | Braid c++ 254 MW,.cpp

```
#include <iostream>

using namespace std;

int main()
{
    int cap, count=0;
    int array[2] = {127,127};

    for (int b1=0; b1<=2; b1++)
    {
        for (int b2=0; b2<=2; b2++)
        {


                cap = ((array[0] * b1) + (array[1] * b2) );

                if(cap == 254)
                {
                    cout<<"b1 = "<<b1 <<"\t";
                    cout<<"b2= "<<b2 <<"\t";
                    cout<<endl;
                    ++count;
                }
            }

    }
    cout<<"\nWe Have "<<count<<" Valid Possible Combinations";
    system("pause");
    return 0;
}
```

Results of the C++ Program for 254 MW:

```
E:\CAPACITY COMBINATION\Braid c++ 254 MW,.exe
b1 = 0  b2= 2
b1 = 1  b2= 1
b1 = 2  b2= 0

We Have 3 Valid Possible CombinationsPress any key to continue . . .
```

Program C++ Simulation for 276 MW:

```
E:\CAPACITY COMBINATION\Braid c++ 276 MW,.cpp - Dev-C++ 5.11
File  Edit  Search  View  Project  Execute  Tools  AStyle  Window  Help
TDM-GCC 4.9.2 64-bit Release
(globals)
Project  Classes  Debug    Braid c++ 254 MW,.cpp   Braid c++ 276 MW,.cpp

#include <iostream>

using namespace std;

int main()
{
    int cap, count=0;
    int array[2] = {138,138};

    for (int b1=0; b1<=2; b1++)
    {
        for (int b2=0; b2<=2; b2++)
        {


                cap = ((array[0] * b1) + (array[1] * b2) );

                if(cap == 276)
                {
                    cout<<"b1 = "<<b1 <<"\t";
                    cout<<"b2= "<<b2 <<"\t";
                    cout<<endl;
                    ++count;
                }
        }

    }
    cout<<"\nWe Have "<<count<<" Valid Possible Combinations";
    system("pause");
    return 0;
}
```

Results of the C++ Program for 276 MW:

```
E:\CAPACITY COMBINATION\Braid c++ 276 MW,.exe
b1 = 0  b2= 2
b1 = 1  b2= 1
b1 = 2  b2= 0

We Have 3 Valid Possible CombinationsPress any key to continue . . .
```

Program C++ Simulation for 450 MW:

E:\CAPACITY COMBINATION\Braid c++ 450 MW,.cpp - [Executing] - Dev-C++ 5.11

File Edit Search View Project Execute Tools AStyle Window Help

TDM-GCC 4.9.2 64-bit Release

(globals)

Project Classes Debug | Braid c++ 254 MW,.cpp | Braid c++ 276 MW,.cpp | Braid c++ 450 MW,.cpp

```cpp
#include <iostream>

using namespace std;

int main()
{
    int cap, count=0;
    int array[6] = {75,75,75,75,75,75};

    for (int b1=0; b1<=6; b1++)
    {
        for (int b2=0; b2<=6; b2++)
        {
            for (int b3=0; b3<=6; b3++)
            {
                for (int b4=0; b4<=6; b4++)
            {

                    for (int b5=0; b5<=6; b5++)
            {

                    for (int b6=0; b6<=6; b6++)
            {

                cap = ((array[0] * b1) + (array[1] * b2) + (array[2] * b3) + (array[3] * b4) + (array[4] * b5) + (array[5] * b6));

                if(cap == 450)
                {
                    cout<<"b1 = "<<b1 <<"\t";
                    cout<<"b2= "<<b2 <<"\t";
                    cout<<"b3= "<<b3 <<"\t";
                    cout<<"b4= "<<b4 <<"\t";
                    cout<<"b5= "<<b5 <<"\t";
                    cout<<"b6= "<<b6 <<"\t";
                    cout<<endl;
                    ++count;
```

Results of the C++ Program for 450 MW:

E:\CAPACITY COMBINATION\Braid c++ 450 MW,.exe

```
b1 = 2   b2= 1   b3= 0   b4= 2   b5= 0   b6= 1
b1 = 2   b2= 1   b3= 0   b4= 2   b5= 1   b6= 0
```

```
b1 = 2   b2= 1   b3= 0   b4= 2   b5= 1   b6= 0
b1 = 2   b2= 1   b3= 0   b4= 3   b5= 0   b6= 0
b1 = 2   b2= 1   b3= 1   b4= 0   b5= 0   b6= 2
b1 = 2   b2= 1   b3= 1   b4= 0   b5= 1   b6= 1
b1 = 2   b2= 1   b3= 1   b4= 0   b5= 2   b6= 0
b1 = 2   b2= 1   b3= 1   b4= 1   b5= 0   b6= 1
b1 = 2   b2= 1   b3= 1   b4= 1   b5= 1   b6= 0
b1 = 2   b2= 1   b3= 1   b4= 2   b5= 0   b6= 0
b1 = 2   b2= 1   b3= 2   b4= 0   b5= 0   b6= 1
b1 = 2   b2= 1   b3= 2   b4= 0   b5= 1   b6= 0
b1 = 2   b2= 1   b3= 2   b4= 1   b5= 0   b6= 0
b1 = 2   b2= 1   b3= 3   b4= 0   b5= 0   b6= 0
b1 = 2   b2= 2   b3= 0   b4= 0   b5= 0   b6= 2
b1 = 2   b2= 2   b3= 0   b4= 0   b5= 1   b6= 1
b1 = 2   b2= 2   b3= 0   b4= 0   b5= 2   b6= 0
b1 = 2   b2= 2   b3= 0   b4= 1   b5= 0   b6= 1
b1 = 2   b2= 2   b3= 0   b4= 1   b5= 1   b6= 0
b1 = 2   b2= 2   b3= 0   b4= 2   b5= 0   b6= 0
b1 = 2   b2= 2   b3= 1   b4= 0   b5= 0   b6= 1
b1 = 2   b2= 2   b3= 1   b4= 0   b5= 1   b6= 0
b1 = 2   b2= 2   b3= 1   b4= 1   b5= 0   b6= 0
b1 = 2   b2= 2   b3= 2   b4= 0   b5= 0   b6= 0
b1 = 2   b2= 3   b3= 0   b4= 0   b5= 0   b6= 1
b1 = 2   b2= 3   b3= 0   b4= 0   b5= 1   b6= 0
b1 = 2   b2= 3   b3= 0   b4= 1   b5= 0   b6= 0
b1 = 2   b2= 3   b3= 1   b4= 0   b5= 0   b6= 0
b1 = 2   b2= 4   b3= 0   b4= 0   b5= 0   b6= 0
b1 = 3   b2= 0   b3= 0   b4= 0   b5= 0   b6= 3
b1 = 3   b2= 0   b3= 0   b4= 0   b5= 1   b6= 2
b1 = 3   b2= 0   b3= 0   b4= 0   b5= 2   b6= 1
b1 = 3   b2= 0   b3= 0   b4= 0   b5= 3   b6= 0
b1 = 3   b2= 0   b3= 0   b4= 1   b5= 0   b6= 2
b1 = 3   b2= 0   b3= 0   b4= 1   b5= 1   b6= 1
b1 = 3   b2= 0   b3= 0   b4= 1   b5= 2   b6= 0
b1 = 3   b2= 0   b3= 0   b4= 2   b5= 0   b6= 1
b1 = 3   b2= 0   b3= 0   b4= 2   b5= 1   b6= 0
b1 = 3   b2= 0   b3= 0   b4= 3   b5= 0   b6= 0
b1 = 3   b2= 0   b3= 1   b4= 0   b5= 0   b6= 2
b1 = 3   b2= 0   b3= 1   b4= 0   b5= 1   b6= 1
b1 = 3   b2= 0   b3= 1   b4= 0   b5= 2   b6= 0
b1 = 3   b2= 0   b3= 1   b4= 1   b5= 0   b6= 1
b1 = 3   b2= 0   b3= 1   b4= 1   b5= 1   b6= 0
b1 = 3   b2= 0   b3= 1   b4= 2   b5= 0   b6= 0
b1 = 3   b2= 0   b3= 2   b4= 0   b5= 0   b6= 1
```

```
b1 = 3  b2= 0  b3= 1  b4= 2  b5= 0  b6= 0
b1 = 3  b2= 0  b3= 2  b4= 0  b5= 0  b6= 1
b1 = 3  b2= 0  b3= 2  b4= 0  b5= 1  b6= 0
b1 = 3  b2= 0  b3= 2  b4= 1  b5= 0  b6= 0
b1 = 3  b2= 0  b3= 3  b4= 0  b5= 0  b6= 0
b1 = 3  b2= 1  b3= 0  b4= 0  b5= 0  b6= 2
b1 = 3  b2= 1  b3= 0  b4= 0  b5= 1  b6= 1
b1 = 3  b2= 1  b3= 0  b4= 0  b5= 2  b6= 0
b1 = 3  b2= 1  b3= 0  b4= 1  b5= 0  b6= 1
b1 = 3  b2= 1  b3= 0  b4= 1  b5= 1  b6= 0
b1 = 3  b2= 1  b3= 0  b4= 2  b5= 0  b6= 0
b1 = 3  b2= 1  b3= 1  b4= 0  b5= 0  b6= 1
b1 = 3  b2= 1  b3= 1  b4= 0  b5= 1  b6= 0
b1 = 3  b2= 1  b3= 1  b4= 1  b5= 0  b6= 0
b1 = 3  b2= 1  b3= 2  b4= 0  b5= 0  b6= 0
b1 = 3  b2= 2  b3= 0  b4= 0  b5= 0  b6= 1
b1 = 3  b2= 2  b3= 0  b4= 0  b5= 1  b6= 0
b1 = 3  b2= 2  b3= 0  b4= 1  b5= 0  b6= 0
b1 = 3  b2= 2  b3= 1  b4= 0  b5= 0  b6= 0
b1 = 3  b2= 3  b3= 0  b4= 0  b5= 0  b6= 0
b1 = 4  b2= 0  b3= 0  b4= 0  b5= 0  b6= 2
b1 = 4  b2= 0  b3= 0  b4= 0  b5= 1  b6= 1
b1 = 4  b2= 0  b3= 0  b4= 0  b5= 2  b6= 0
b1 = 4  b2= 0  b3= 0  b4= 1  b5= 0  b6= 1
b1 = 4  b2= 0  b3= 0  b4= 1  b5= 1  b6= 0
b1 = 4  b2= 0  b3= 0  b4= 2  b5= 0  b6= 0
b1 = 4  b2= 0  b3= 1  b4= 0  b5= 0  b6= 1
b1 = 4  b2= 0  b3= 1  b4= 0  b5= 1  b6= 0
b1 = 4  b2= 0  b3= 1  b4= 1  b5= 0  b6= 0
b1 = 4  b2= 0  b3= 2  b4= 0  b5= 0  b6= 0
b1 = 4  b2= 1  b3= 0  b4= 0  b5= 0  b6= 1
b1 = 4  b2= 1  b3= 0  b4= 0  b5= 1  b6= 0
b1 = 4  b2= 1  b3= 0  b4= 1  b5= 0  b6= 0
b1 = 4  b2= 1  b3= 1  b4= 0  b5= 0  b6= 0
b1 = 4  b2= 2  b3= 0  b4= 0  b5= 0  b6= 0
b1 = 5  b2= 0  b3= 0  b4= 0  b5= 0  b6= 1
b1 = 5  b2= 0  b3= 0  b4= 0  b5= 1  b6= 0
b1 = 5  b2= 0  b3= 0  b4= 1  b5= 0  b6= 0
b1 = 5  b2= 0  b3= 1  b4= 0  b5= 0  b6= 0
b1 = 5  b2= 1  b3= 0  b4= 0  b5= 0  b6= 0
b1 = 6  b2= 0  b3= 0  b4= 0  b5= 0  b6= 0

We Have 462 Valid Possible CombinationsPress any key to continue . . .
```

Program C++ Simulation for 2250 MW:

E:\CAPACITY COMBINATION\Braid c++ 2250 MW,.cpp - [Executing] - Dev-C++ 5.11

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TDM-GCC 4.9.2 64-bit Release

(globals)

Project Classes Debug | Braid c++ 2250 MW,.cpp

```cpp
int array[6] = {75,75,75,75,75,75};

for (int b1=0; b1<=30; b1++)
{
    for (int b2=0; b2<=30; b2++)
    {
        for (int b3=0; b3<=30; b3++)
        {
            for (int b4=0; b4<=30; b4++)
        {

                for (int b5=0; b5<=30; b5++)
        {

                for (int b6=0; b6<=30; b6++)
        {

            cap = ((array[0] * b1) + (array[1] * b2) + (array[2] * b3) + (array[3] * b4) + (array[4] * b5) + (array[5] * b6));

            if(cap == 2250)
            {
                cout<<"b1 = "<<b1 <<"\t";
                cout<<"b2= "<<b2 <<"\t";
                cout<<"b3= "<<b3 <<"\t";
                cout<<"b4= "<<b4 <<"\t";
                cout<<"b5= "<<b5 <<"\t";
                cout<<"b6= "<<b6 <<"\t";
                cout<<endl;
                ++count;
            }
        }
    }
  }}}
}
cout<<"\nWe Have "<<count<<" Valid Possible Combinations";
system("pause");
```

Results of the C++ Program for 2250 MW:

E:\CAPACITY COMBINATION\Braid c++ 2250 MW,.exe

```
b1 = 5  b2= 7   b3= 4   b4= 2   b5= 7   b6= 5
b1 = 5  b2= 7   b3= 4   b4= 2   b5= 8   b6= 4
b1 = 5  b2= 7   b3= 4   b4= 2   b5= 9   b6= 3
b1 = 5  b2= 7   b3= 4   b4= 2   b5= 10  b6= 2
b1 = 5  b2= 7   b3= 4   b4= 2   b5= 11  b6= 1
b1 = 5  b2= 7   b3= 4   b4= 2   b5= 12  b6= 0
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 0   b6= 11
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 1   b6= 10
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 2   b6= 9
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 3   b6= 8
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 4   b6= 7
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 5   b6= 6
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 6   b6= 5
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 7   b6= 4
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 8   b6= 3
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 9   b6= 2
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 10  b6= 1
b1 = 5  b2= 7   b3= 4   b4= 3   b5= 11  b6= 0
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 0   b6= 10
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 1   b6= 9
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 2   b6= 8
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 3   b6= 7
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 4   b6= 6
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 5   b6= 5
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 6   b6= 4
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 7   b6= 3
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 8   b6= 2
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 9   b6= 1
b1 = 5  b2= 7   b3= 4   b4= 4   b5= 10  b6= 0
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 0   b6= 9
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 1   b6= 8
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 2   b6= 7
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 3   b6= 6
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 4   b6= 5
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 5   b6= 4
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 6   b6= 3
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 7   b6= 2
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 8   b6= 1
b1 = 5  b2= 7   b3= 4   b4= 5   b5= 9   b6= 0
b1 = 5  b2= 7   b3= 4   b4= 6   b5= 0   b6= 8
b1 = 5  b2= 7   b3= 4   b4= 6   b5= 1   b6= 7
b1 = 5  b2= 7   b3= 4   b4= 6   b5= 2   b6= 6
b1 = 5  b2= 7   b3= 4   b4= 6   b5= 3   b6= 5
```

Program C++ Simulation for Feb 7 2017 AB:

E:\CAPACITY COMBINATION\Braid c++ feb 7 2017 AB.cpp - [Executing] - Dev-C++ 5.11

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TDM-GCC 4.9.2 64-bit Release

(globals)

Project Classes Debug | Braid c++ 2250 MW,.cpp | Braid c++ feb 7 2017 AB.cpp

```
#include <iostream>

using namespace std;

int main()
{
    int cap, count=0;
    int array[6] = {75,75,75,75,75,75};

    for (int b1=0; b1<=30; b1++)
    {
        for (int b2=0; b2<=30; b2++)
        {
            for (int b3=0; b3<=30; b3++)
            {
                for (int b4=0; b4<=30; b4++)
                {

                    for (int b5=0; b5<=30; b5++)
                {

                    for (int b6=0; b6<=30; b6++)
                {

                cap = ((array[0] * b1) + (array[1] * b2) + (array[2] * b3) + (array[3] * b4) + (array[4] * b5) + (array[5] * b6));

                if(cap == 2250)
                {
                    cout<<"b1 = "<<b1 <<"\t";
                    cout<<"b2= "<<b2 <<"\t";
                    cout<<"b3= "<<b3 <<"\t";
                    cout<<"b4= "<<b4 <<"\t";
                    cout<<"b5= "<<b5 <<"\t";
                    cout<<"b6= "<<b6 <<"\t";
                    cout<<endl;
                    ++count;
```

Results of the C++ Program for Feb 7 2017 AB:

E:\CAPACITY COMBINATION\Braid c++ feb 7 2017 AB.exe

```
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 1   b6= 19
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 2   b6= 18
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 3   b6= 17
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 4   b6= 16
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 5   b6= 15
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 6   b6= 14
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 7   b6= 13
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 8   b6= 12
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 9   b6= 11
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 10  b6= 10
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 11  b6= 9
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 12  b6= 8
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 13  b6= 7
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 14  b6= 6
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 15  b6= 5
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 16  b6= 4
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 17  b6= 3
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 18  b6= 2
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 19  b6= 1
b1 = 3  b2= 4   b3= 2   b4= 1   b5= 20  b6= 0
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 0   b6= 19
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 1   b6= 18
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 2   b6= 17
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 3   b6= 16
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 4   b6= 15
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 5   b6= 14
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 6   b6= 13
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 7   b6= 12
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 8   b6= 11
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 9   b6= 10
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 10  b6= 9
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 11  b6= 8
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 12  b6= 7
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 13  b6= 6
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 14  b6= 5
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 15  b6= 4
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 16  b6= 3
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 17  b6= 2
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 18  b6= 1
b1 = 3  b2= 4   b3= 2   b4= 2   b5= 19  b6= 0
b1 = 3  b2= 4   b3= 2   b4= 3   b5= 0   b6= 18
b1 = 3  b2= 4   b3= 2   b4= 3   b5= 1   b6= 17
b1 = 3  b2= 4   b3= 2   b4= 3   b5= 2   b6= 16
b1 = 3  b2= 4   b3= 2
```

Program C++ Simulation for Feb 7 2017 ABC:

E:\CAPACITY COMBINATION\Braid c++ feb 7 2017 ABC.cpp - [Executing] - Dev-C++ 5.11

```cpp
#include <iostream>

using namespace std;

int main()
{
    int cap, count=0;
    int array[2] = {127,127};

    for (int b1=0; b1<=2; b1++)
    {
        for (int b2=0; b2<=2; b2++)
        {


                cap = ((array[0] * b1) + (array[1] * b2) );

                if(cap == 254)
                {
                    cout<<"b1 = "<<b1 <<"\t";
                    cout<<"b2= "<<b2 <<"\t";
                    cout<<endl;
                    ++count;
                }
            }

    }
    cout<<"\nWe Have "<<count<<" Valid Possible Combinations";
    system("pause");
    return 0;
}
```

Results of the C++ Program for Feb 7 2017 ABC:

E:\CAPACITY COMBINATION\Braid c++ feb 7 2017 ABC.exe

```
b1 = 0  b2= 2
b1 = 1  b2= 1
b1 = 2  b2= 0

We Have 3 Valid Possible CombinationsPress any key to continue . . .
```