

Utilizing Rooftops Space of Large Government Buildings for Sustainable Electricity Distributed Generation Economy

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ABSTRACT

This study proposes a solar Distributed Generation (DG) system for Awka, Anambra State, utilizing rooftops of major government buildings—Awka City Stadium, Alex Ekwueme Square, and the International Conference Center—to deploy 1,000 pieces of 450W solar panels, generating 270kW of electricity. The system serves small-scale (200–1,000W), medium-scale (1.1–5kW), and large-scale (5.1–10kW) consumers at daily tariffs of ₦2,000, ₦5,000, and ₦15,000, respectively, powering 250, 50, or 25 consumers per category. It also supports 200 pieces of 100W floodlights for 12-hour nightly operation, enhancing urban infrastructure. Project costs are estimated at ₦430.3 million over 5 years, ₦891.5 million over 15 years, and ₦1.48 billion over 25 years. Economic analysis projects 5-year outcomes of ₦409.7 million profit (small-scale), ₦10.3 million loss (medium-scale), and ₦199.7 million profit (large-scale); 15-year profits of ₦1.63 billion, ₦368.5 million, and ₦998.5 million; and 25-year profits of ₦2.72 billion, ₦618.2 million, and ₦1.67 billion, respectively. This scalable, cost-effective DG model enhances energy access, reduces grid dependency, and fosters economic growth in Awka, providing a replicable framework for sustainable urban energy solutions across Nigeria and informing regional renewable energy policies.

Keywords: Distributed generation, renewable energy, building rooftop, solar system, electricity consumers.

INTRODUCTION

Independent power generating stations have been found to be required for installations at locations where it can be beneficial. Distributed generations (DG) comprise of generation and distribution system installed for use within a locality. Solar systems have been of immense contribution towards independent power generation throughout the globe with interest within Nigeria's electricity prospects. Setting up such electricity generation systems from renewable energy systems such as solar require vast land area for solar panels to be installed. The technology of solar Photovoltaic (PV) have been of immense contribution to the amount of electricity power generation in Anambra state. Electricity generation is an action of a progressive government in a country. The population of countries in Africa such as Nigeria is ever increasing in geometric measure with population of Nigeria estimated at about 226.2 million as of December 2023 (Doris, 2023). Renewable energy system such as solar, wind, hydro, tides, etc can be harnessed for use at where such renewable energy sources are predominant. Educational institutions such as universities, secondary schools can harness renewable energy sources such as solar and biomass available to provide electricity for their campus (Nworabude, 2023). It is important to look around our environment to identify predominant energy sources to harness for use. Rooftop of buildings serves great deal of protection against rain, snow, sunlight, wind and extreme temperatures (Ayuba and Agah, 2018). Large rooftops can provide required large area for mounting large number of solar PV (photovoltaic) modules popularly referred to as solar panels use in electricity generation.

Generating more electricity should be a deliberate effort of each government with the new Electricity Act 2023 signed into law for electricity generation not above 1MW and distribution not more than 100kW (NERC, 2023). Responsible state government should start making effort to supply unlimited electricity to her citizens. This paper suggests ways of generating electricity using available rooftops of large government buildings for solar

PV system installation capable of generating about 270kW of electricity for use. Electricity generated from this DG solar PV systems can be used to power businesses, offices, homes within its vicinity as well as power street lightning during nighttime.

METHOD

This paper presents a power generating process of utilizing roof space of large government buildings to provide electricity for small scale business, offices, homes located close to the buildings for electricity generation. Implementing solar PV systems for electricity generation and viable business venture, the procedures required include:

1. Calculate the area of roof top space of selected building to be used for power generation.
2. Select equipment (such as solar panels, inverters, batteries, etc.) for power generation implementation.
3. Estimate power generation capacity and distribution potentials of the solar system
4. Estimate cost of project and revenue generation possibilities of the system.
5. Calculate profit/loss on investment.

Calculation of Roof Top Space of Government Buildings

This paper highlights three government buildings for implementation of the power generation projects.

A. Awka City Stadium

The roof top of one rectangular side of a standard stadium is 110m x 40m (Zhong et. Al, 2021). However, Awka City Stadium fall short of standard roof size of stadiums.

B. Alex Ekwueme Square

This is one of the biggest gathering centers for outdoor events in Anambra State known mostly for venue during rallies of political parties, trade unions, Independence Day parade and swearing-in ceremony of governor, etc (Wikiwand, 2023).

C. International Conference Center (ICC)

This center is tagged with 10,000 capacity (Abana, 2021). Event centers such as EKO Convention Center and Landmark Event Centre had impressive floor space of 5,151 and 4,200 square meters (Private property, 2023). EKO Convention Center has capacity to host conferences for up to 3,000 attendees while International Conference Center (ICC) Awka has a whopping capacity of 10,000 attendees. Despite the massive floor space of ICC Awka, 4,000 square meter roof-top size will be adopted for this study.

Selecting Equipment

Solar Panels

Selecting solar panels depends mostly on prices, efficiency of solar cells embedded on the solar panels. Nigeria market is flooded with many products ranging with various prices. The study adopted Felicity Solar brand of products which may be ordered from the production company in China. The brand seems to have penetrated the Nigeria market with trusted products and technology. Table 1 presents the product specification of selected model

Table 1: Product Specification of Solar panel

Parameter	Value
Company/Model	Felicity Solar 132-450W
Peak power	450 W

Open circuit voltage (V_{OC})	41.85 V
Maximum power voltage (V_{mp})	35.29 V
Maximum power current (I_{mp})	12.75 A
Short circuit current (I_{SC})	14.69 A
Cell type	Monocrystalline silicon
Dimension	1960 x 1060x 35 mm
Price	₦ 139,000

Inverter

This component is charged with the responsibility of inverting direct current (dc) supplied by the battery to alternating current (ac) for use by electronic gadget and appliances.

Table 2: Product Specification of Inverter

Parameter	Value
Company/Model	Felicity Solar IVPS10048
Rated output power	1000VA (8000W)
Nominal DC input voltage	48 V
Nominal input voltage	220 Vac
Nominal input frequency	50 Hz / 60 Hz
Max AC input voltage	280 Vrms
Efficiency (line mode)	≥ 95%
Charger short circuit	63 A
Price	₦ 1,605,000

Batteries

The batteries characterized for storing energy for use. The batteries are charged during the sun hours when the solar panels are generating electricity.

Table 3: Product Specification of Battery

Parameter	Value
Company/Model	Felicity Solar LPBF48250
Usable capacity	12.5 kWh
Nominal voltage	51.2 V
Voltage range	48 – 57.6 V
Recommended charge and discharge current	≤ 120 A

Max. charge and discharge current	200 A @15 S
Recommended output power	≤ 6000 W
DOD	> 95%
Cycle life	≥ 6000 @25°C, 80% DOD
Net weight	154 KG
Dimension	615 x 350 x 955 mm
Price	₦ 4,270,000

Charge Controller

This is charged with the responsibility of charging the batteries. It regulates current used in charging the batteries by utilizing the energy generated from the solar panels.

Table 4: Product Specification of Charge Controller

Parameter	Value
Company/Model	Felicity Solar SCCM12048
Nominal system voltage	12, 24, 48 VDC (Auto detection)
PV start-up voltage	41.85 V
PV Array MPPT voltage range	12 VDC / 24 VDC / 48 VDC
	15-170 V / 30-170 V / 60-170 V
Maximum input power	12 V – 1650 W
	24 V – 3300 W
	48 V – 6600 W
Transient surge protection	4500 Watts / port
Net weight	6.5 kg
Dimension	319 x 218 x 118 mm
Price	₦ 394,000

Power Generation Estimation

Calculating quantity of power to be generated from selected site locations having selected required components is determine thus:

Awka City Stadium

Estimated size of rooftop = 1000 m²

Size of solar panel (450W)

= 1960mm x 1060mm = 1.96m x 1.06m

$$= 2.08 \text{ m}^2$$

Number of solar panels expected

$$= 1000/2.08 = 480 \text{ panels}$$

Number of panels permissible = 400 panels

power generation capacity

$$= 400 \times 450 \text{ W} = 180 \text{ kW}$$

Realizable power capacity

$$= 180 \text{ kW} \times 0.6 = 108 \text{ kW}$$

Alex Ekwueme Square

Estimated size of rooftop = 1000 m^2

Size of solar panel (450W)

$$= 1960\text{mm} \times 1060\text{mm} = 1.96\text{m} \times 1.06\text{m}$$

$$= 2.08 \text{ m}^2$$

Number of solar panels expected

$$= 1000/2.08 = 480 \text{ panels}$$

Number of panels permissible = 400 panels

power generation capacity

$$= 400 \times 450 \text{ W} = 180 \text{ kW}$$

Realizable power capacity

$$= 180 \text{ kW} \times 0.6 = 108 \text{ kW}$$

International Conference Center (ICC)

Estimated size of rooftop = 4000 m^2

Size of solar panel (450W)

$$= 1960\text{mm} \times 1060\text{mm} = 1.96\text{m} \times 1.06\text{m} = 2.08 \text{ m}^2$$

Number of solar panels expected

$$= 4000/2.08 = 1,923 \text{ panels}$$

Number of panels permissible

$$= 1000 \text{ panels}$$

power generation capacity

$$= 1000 \times 450 \text{ W} = 450 \text{ kW}$$

Realizable power capacity

$$= 450 \text{ kW} \times 0.6 = 270 \text{ kW}$$

No of inverter needed

$$= 27 \text{ pieces} \times 10 \text{ kW} = 270 \text{ kW}$$

No of solar panels per inverter

$$= 1000/27 = 37 \text{ panels each}$$

Actual no of panels per 10 kW inverter installation = 4 x 9 panels = 36 panels

Total usable no of solar panels

$$= 4 \times 9 \times 27 = 972 \text{ panels}$$

No of back-up batteries capacity per inverter installation

$$= 12.5 \text{ kWh} \times 2 = 25 \text{ kWh}$$

Total back-up batteries capacity

$$= 12.5 \text{ kWh} \times 2 \times 27 = 675 \text{ kWh}$$

No of charge controllers per inverter connection = 2

Total no of charge controllers

$$= 2 \times 27 = 54 \text{ charge controllers}$$

Table 5: Project Cost Estimation

S/N	Components	Unit cost ₦	Total cost ₦	Replacement cost (₦)	Validity (no of years)
1	Solar panels	139,000	135,108,000	Nil	25
2	Inverter	1,605,000	43,335,000	86,670,000	15
3	Batteries	4,270,000	230,580,000	922,320,000	5
4	Charge controller	394,000	21,276,000	42,552,000	15
	Total		430,299,000	1,051,542,000	25
			1,481,841,000		

This project is capable of generating 270kW of electricity in the state capital Awka for use by residents/customers within the generation locations. Power generated on these selected locations will be distributed for use by consumers within the locations. These consumers may be charged on daily basis or metered based on a calculated energy cost per Wh. Powering businesses, homes and offices within the selected locations will be the most effective use of power generated by the DG. This system can also be used during night hours to power street lightnings installed at electric poles within the installed locations.

Table 6: Power Distribution Capabilities

	Small-scale consumers (200 – 1000 W)	Medium scale consumers (2 – 5 kW)	Large scale consumers (5 – 10 kW)
Estimated consumers	> 270 consumers	> 27 consumers	> 5 consumers
Type of consumers	Small-scale businesses, homes	Medium scale businesses, homes, schools	High electricity demand business, market, small factories

Table 7: Revenue Generation while Supplying 250 kW

	Electricity Cost	No of consumers	Daily	Weekly	Monthly	Annually
Small-scale consumers (200-1000W)	@ 2000 per day	1 consumer	2,000	14,000	98,000	1,176,000
		250 consumers	500,000	3,500,000	14,000,000	168,000,000
Mediumscale consumers (1.1 – 5 kW)	@5000 per day	1 consumer	5,000	35,000	140,000	1,680,000
		50 consumers	250,000	1,750,000	7,000,000	84,000,000
Large scale consumers (5.1 - 10 kW)	@15,000 per day	1 consumer	15,000	105,000	420,000	5,040,000
		25 consumers	375,000	2,625,000	10,500,000	126,000,000

Table 8: Project Cash Flow within Years of Operation

S/N	Years of operation	Project cost	Consumers	Project Revenue	Profit/Loss
1	5	430,299,000	Small-scale	840,000,000	409,701,000
			Medium-scale	420,000,000	-10,299,000
			Large-scale	630,000,000	199,701,000
2	15	891,459,000	Small-scale	2,520,000,000	1,628,541,000
			Medium-scale	1,260,000,000	368,541,000
			Large-scale	1,890,000,000	998,541,000
3	25	1,481,841,000	Small-scale	4,200,000,000	2,718,159,000
			Medium-scale	2,100,000,000	618,159,000
			Large-scale	3,150,000,000	1,668,159,000

Table 8 presents project cost estimation, revenue made from electricity consumers for period of 5 years, 15 years and 25 years of operation. The 25 years validity was chosen since that is validity period for the longest lasting component - solar PV modules (solar panels).

RESULTS

The mathematical requirements calculated and tabulated showed the business of power generation and distribution to consumers within the selected locations. It has shown that businesses (small, medium and few large scale) can be powered daily uninterruptible and profits made from such sustainable power generation projects. Presenting the graph of figure 1, electricity generation of 270 kW can power about 250 small scale consumers of 200-1000W or 50 medium scale consumers of 1-5kW or 25 large scale consumers of 5-10kW.

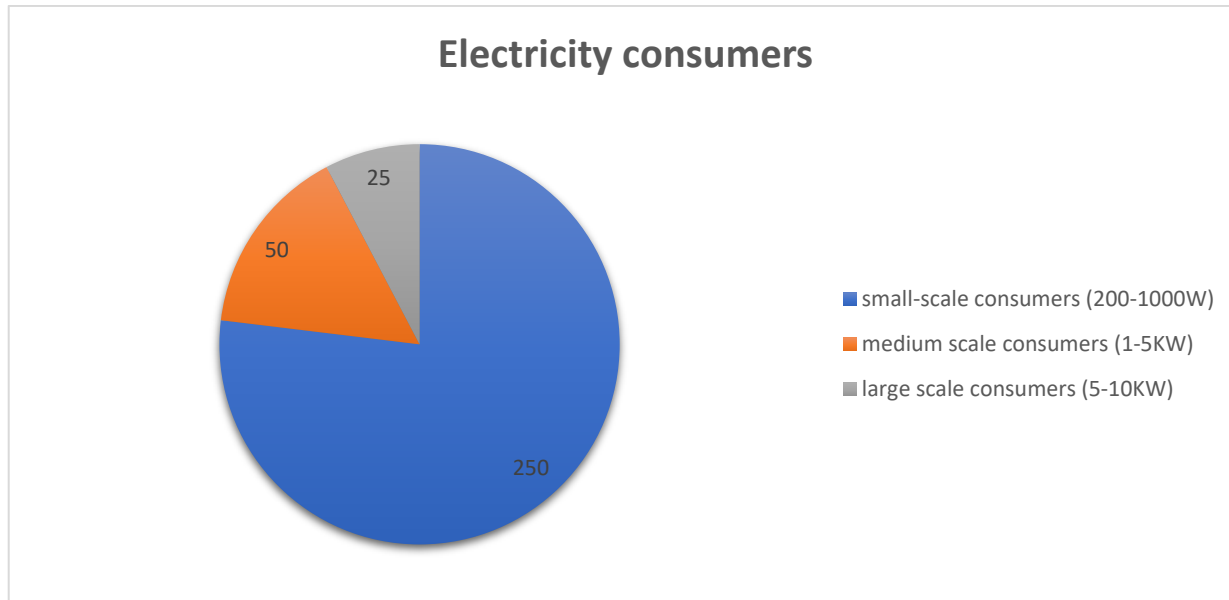


Figure 1: Capacity of electricity consumers

Small scale consumers include small businesses (such as barbing/hair salons), homes. Medium scale consumers include medium businesses (such as retail stores, supermarkets), homes, schools, etc. Large scale consumers include businesses such as computer centers, café, schools, homes, etc.

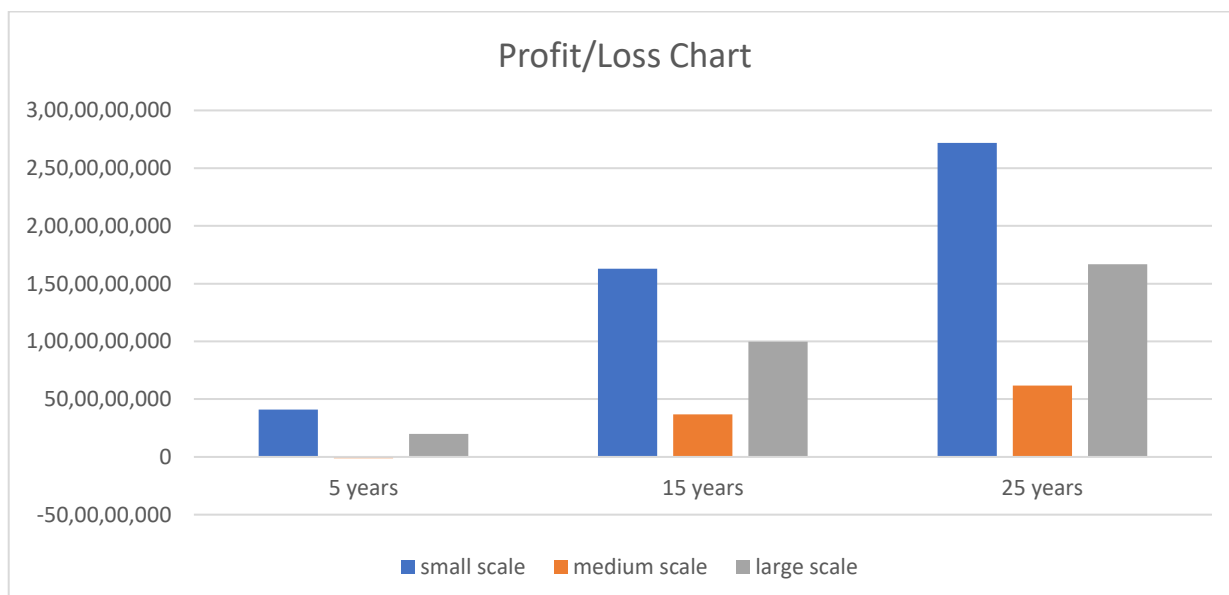


Figure 2: Profit/Loss Chart of the Distributed Generation Stations

Data presented in figure 2 was taken from table 8 Profit/Loss column. It presents profits and losses made by supplying consumers (small, medium and large scale) electricity to power their businesses, homes, offices, etc. These consumers may be charge daily, monthly or via pay-as-you-go basis and revenue generated for sustaining the DG stations.

DISCUSSIONS

This paper presents a road map for power generation in Awka, capacity city Anambra state. The power generation capabilities presented in this paper can be replicated at other locations within the city (Awka) and even at other cities with large buildings such as Onitsha and Nnewi within the state. It is important to note that the calculations presented in this paper is based on cost of procuring the project major components only without considering the cost of installation and other minor components required for the installation. However, having presented this paper major input which is about providing unlimited electric power within the project localities for consumption by consumers, it is eminent to note that this distribution generation project is capable of powering daily during night hours about 200 pieces of 100W flood light within the state. This can be achieved by installing a small diameter cable on the low-tension distribution line and the 100W flood lights tightened at the poles for connection to the cable already installed at the poles.

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