Electric Energy Supply In Nigeria, Decentralized Energy Approach

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Abstract: The analysis of Nigeria's electricity supply problems and prospects was done. The electricity demand in Nigeria far outstrips the supply which is epileptic in nature. The acute electricity supply hinders the country's development notwithstanding the availability of vast natural resources in the country. Nigeria is endowed with abundant renewable energy resources, the significant ones being solar energy, biomass, wind, small and large hydropower with potential for hydrogen fuel, geothermal and ocean energies. Decentralized Energy (DE) is the production of electricity at or near the point of use, irrespective of size, fuel or technology. The adoption of renewable energy technologies in a Decentralized Energy (DE) manner especially for rural communities and in stand-alone applications will improved electricity supply and enhance the overall economic development. [New York Science Journal. 2009;2(5):84-92]. (ISSN: 1554-0200).

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1. Introduction

With its rich supply of natural resources, Nigeria has become, quite naturally, heavily dependent on fossil fuels. But while thermal plants supply about 60 percent of our stationary energy grid and petroleum products help meet our transportation needs, we must continue to find ways to both reduce our dependence on fossil fuels and make our consumption of them less harmful to the environment.

Replacing fossil fuels with renewable energy is the ultimate goal, but as they currently account for 80% of global energy demand, it is not yet possible to do so and sustain even a basic standard of living. Indeed, although the volume of renewable is increasing at an enormous rate, it is still being outstripped by rising energy demand [1].

Electricity plays a very important role in the socio-economic and technological development of every nation. The electricity demand in Nigeria far outstrips the supply and the supply is epileptic in nature. The country is faced with acute electricity problems, which is hindering its development notwithstanding the availability of vast natural resources in the country. It is widely accepted that there is a strong correlation between socio-economic development and the availability of electricity.

The history of electricity in Nigeria dates back to 1896 when electricity was first produced in Lagos, fifteen years after its introduction in England. Despite the fact that its existence in the country is over a century, its development has been at a slow rate. In 1950, a central body was established by the legislative council, which transferred electricity supply and development to the care of the central body known then as the Electricity Corporation of Nigeria. Other bodies like Native Authorities and Nigeria Electricity Supply Company (NESCO) have licenses to produce electricity in some locations in Nigeria. Another body known as Niger Dams Authority (NDA) was established by an act of parliament. The Authority was responsible for the construction and maintenance of dams and other works on the River Niger and elsewhere generating electricity by means of water power, improving and promoting fish brines and irrigation. The energy produced by NDA was sold to the Electricity Corporation of Nigeria for distribution and sales at utility voltages.

For over twenty years prior to 1999, the power sector did not witness substantial investment in infrastructural development. During that period, new plants were not constructed and the existing ones were not properly maintained, bringing the power sector to a deplorable state. In 2001, generation went down from the installed capacity of about 5,600MW to an average of about 1,750MW, as compared to a load demand of 6,000MW [2].

Nigeria Electric network grid is shown in Figure 1 below.

Figure 1. Nigeria Electric Grid Network. Source: Global Energy Network Institute (GENI)

2. Resources for Electricity Generation in Nigeria

Nigeria is a country that is blessed with a lot of resources that can be used to generate electricity such as coal, natural gas, oil, hydro and other renewable energy sources.

2.1 Coal

Coal was first discovered in Nigeria in 1909. Coal mining in Nigeria began in 1916 with a recorded output of 24,500 tons. Production rose to a peak of 905,000 tonnes in the 1958/59 with a contribution of over 70%

to commercial energy consumption in the country. Available data show that coal of sub-bituminous grade occurs in about 22 coal fields spread in over 13 States of the Federation. The proven coal reserves so far in the country are about 639 million tonnes while the inferred reserves are about 2.75 billion tonnes. Following the discovery of crude oil in commercial quantities in 1958 and the conversion of railway engines from coal to diesel, production of coal fell from the beginning of the sixties to only 52,700 tonnes in 1983 and contributed about 0.02% to commercial energy consumption in the country in 2001.

2.2 Oil

Oil exploration in Nigeria witnessed steady growth over the past few years. The nation had a proven reserve of 25 billion barrels of predominantly low sulphur light crude in 1999. This substantially increased to 34 billion barrels in 2004 and currently is about 36.5 billion barrels. The growth in reserves is attributable to improved funding of Joint Venture operations, timely payment of cash call arrears, introduction of an alternative funding scheme, the emergence of new production sharing arrangements and the opening up of new frontier and deepwater / offshore blocks. Based on various oil prospects already identified especially in the deepwater terrain and the current (2006) development efforts, it is projected that proven reserves will reach about 40 billion barrels by year 2010 and potentially 68 billion barrels by year 2030. Oil production in the country also increased steadily over the years; however, the rate of increase is dependent on economic and geopolitics in both producing and consuming countries. Nigeria's current production capacity is about 2.4 million barrels per day even though actual production is averaging around 2.4 million barrels per day partly due to the problems in the Niger Delta and OPEC production restriction. Average daily production is projected to increase to 4.0 million barrels per day by 2010 and potentially to over 5.0 million per day in year 2030.

In the downstream oil sub-sector, Nigeria has four refineries with a total installed capacity of 445,000 barrels per day and 5001 km network of pipeline from the refineries to 22 oil depots. The Federal Government also established petrochemical and fertilizer plants. The capacity utilization of these plants and facilities has been considerably low, due to the high level of decay arising from poor maintenance and operating conditions, under -funding, vandalization especially on the pipelines, and the various companies' lack of management autonomy for efficient operation. Consequently, annual domestic demand for petroleum products is not fully met by internal production and has to be supplemented by imports.

2.3 Natural Gas

Nigeria's proven natural gas reserves, estimated at about 187.44 trillion standard cubic feet in 2005, are known to be substantially larger than its oil resources in energy terms. Gas discoveries in Nigeria are incidental to oil exploration and production activities. Consequently, as high as 75% of the gas produced was being flared in the past. However, gas flaring was reduced to about 36% as a result of strident efforts by the Government to monetize natural gas. Domestic utilization of Natural gas is mainly for power generation which accounted for over 80% while the remaining are in the industrial sector and very negligible in the household sector. Given the current reserves and rate of exploitation, the expected life-span of Nigerian crude oil is about 44 years, based on about 2mb/d production, while that for natural gas is about 88 years, based on the 2005 production rate of 5.84 bscf/day.

2.4 Renewable Energy

Nigeria is endowed with abundant renewable energy resources, the significant ones being solar energy, biomass, wind, small and large hydropower with potential for hydrogen fuel, geothermal and ocean energies. The estimated capacity of the main renewable energy resources.

Except for large scale hydropower which serves as a major source of electricity, the current state of exploitation and utilization of the renewable energy resources in the country is very low, limited largely to pilot and demonstration projects.

The main constraints in the rapid development and diffusion of technologies for the exploitation and utilization of renewable energy resources in the country are the absence of market and the lack of appropriate policy, regulatory and institutional framework to stimulate demand and attract investors. The comparative low quality of the systems developed and the high initial upfront cost also constitute barriers to the development of markets.

2.4.1 **Hydropower**

Essentially, hydropower systems rely on the potential energy difference between the levels of water in reservoirs, dams or lakes and their discharge tail water levels downstream. The water turbines which convert the potential energy of water to shaft rotation are coupled to suitable generators.

The hydropower potential of Nigeria is very high and hydropower currently accounts for about 29% of the total electrical power supply. The first hydropower supply station in Nigeria is at Kainji on the river Niger where the installed capacity is 836MW with provisions for expansion to 1156 MW. A second hydropower station on the Niger is at Jebba with an installed capacity of 540 MW. An estimate for rivers Kaduna, Benue and Cross River (at Shiroro, Makurdi and Ikom, respectively) indicates their total capacity to stand at about 4,650 MW. Estimates for the rivers on the Mambila Plateau are put at 2,330MW. The overall hydropower resources potentially exploitable in Nigeria are in excess of 11,000MW [3].

Indeed small-scale (both micro and mini) hydropower systems possess the advantage, over large hydro systems, that problems of topography are not excessive. In effect, small hydropower systems can be set up in all parts of the country so that the potential energy in the large network of rivers can be tapped and converted to electrical energy. In this way the nation's rural electrification projects can be greatly enhanced.

2.4.2 **Solar Energy**

Solar radiation is the radiant energy that is emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy. The knowledge of the amount of solar radiation in a given location is essential in the field of solar energy physics. This in effect helps us to have a fair knowledge of the insolation power potential over the location [4].

Solar energy is the most promising of the renewable energy sources in view of its apparent limitless potential. The sun radiates its energy at the rate of about 3.8 x 1023 kW per second. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.5kW/m^2 at the boundary of the atmosphere. After traversing the atmosphere, a square metre of the earth's surface can receive as much as 1kW of solar power, averaging to about 0.5 over all hours of daylight. Studies relevant to the availability of the solar energy resource in Nigeria have fully indicated its viability for practical use. Although solar radiation intensity appears rather dilute when compared with the volumetric concentration of energy in fossil fuels, it has been confirmed that Nigeria receives 5.08 x 1012 kWh of energy per day from the sun and if solar energy appliances with just 5% efficiency are used to cover only 1% of the country's surface area then 2.54 x 106 MWh of electrical energy can be obtained from solar energy. This amount of electrical energy is equivalent to 4.66 million barrels of oil per day.

Solar energy technologies are divided into two broad groups namely solar-thermal and solar photovoltaic. In solar thermal applications, solar energy, as electromagnetic waves, is first converted into heat energy. The heat energy may then be used either directly as heat, or converted into 'cold', or even into electrical or mechanical energy forms.

Typical such applications are in drying, cooking, heating, distillation, cooling and refrigeration as well as electricity generation in thermal power plants.

In solar photovoltaic applications, the solar radiation is converted directly into electricity. The most common method of doing this is through the use of silicon solar cells. The power generating unit is the solar module which consists of several solar cells electrically linked together on a base plate. On the whole the major components of a photovoltaic system include the arrays which consist of the photovoltaic conversion devices, their interconnections and support, power conditioning equipment that convert the dc to ac and provides regulated outputs of voltage and current; controller, which automatically manages the operation of the total system; as well as the optional storage for stand alone (non-grid) systems.

2.4.3 Biomass

Biomass energy refers to the energy of biological systems such as wood and wastes. Biomass energy is an indirect form of solar energy because it arises due to photosynthesis. The biomass resources of Nigeria can be identified as wood biomass, forage grasses and shrubs, residues and wastes (forestry, agricultural, municipal and industrial) as well as aquatic biomass.

Wood, apart from being a major source of energy in the form of fuel wood is also used for commercial purposes in various forms as plywood, sawn wood, paper products and electric poles. For energy purposes, Nigeria is using 80 million cubic metres (43.4 x 109 kg) of fuel wood annually for cooking and other domestic purposes. The energy content of fuel wood that is being used is 6.0 x 109MJ out of which only between 5 - 12% is the fraction that is gainfully utilized for cooking and other domestic uses.

2.4.4 Wind Energy

Wind is a natural phenomenon related to the movement of air masses caused primarily by the differential solar heating of the earth's surface. Seasonal variations in the energy received from the sun affect the strength and direction of the wind. The ease with which wind turbines transform energy in moving air to rotary mechanical energy suggests the use of electrical devices to convert wind energy to electricity. Wind energy has also been utilized, for decades, for water pumping as well as for the milling of grains.

A study on the wind energy potentials for a number of Nigerian cities shows that the annual wind speed ranges from 2.32 m/s for Port Harcourt to 3.89 m/s for Sokoto. The maximum extractable power per unit area, for the same two sites was estimated as 4.51 and 21.97 watts per square metre of blade area, respectively. When the duration of wind speeds greater than 3 m/s is considered than the energy per unit area is 168.63 and 1,556.35 kWh per square metre of blade area, again for Port-Harcourt and Sokoto.

Although use of wind energy for water supply has been known and used for hundreds of years, in recent times efforts have been directed largely towards the use of wind power for the generation of electricity and in the past twenty years or so rapid changes in technology have occurred and major wind powered generating plants have been installed, especially in the rural areas of the developed countries.

3. Inefficient and Unreliable Energy Supply System

In electric energy supply efficiencies of existing thermal plants are low. They are as low as 12% whereas efficiencies of up to 40% are attainable with modern technologies. Also substantial electricity is lost during transmission and distribution. These losses are sometimes more than 30% of the total electricity generated. Apart from these inefficiencies the reliability and availability of existing installed electric generation system is low. There is the serious problem of power unreliability over the years such that most industrial establishments and upper income households install very expensive generating sets amounting to over half of the total installed grid capacity. This constitutes huge economic losses to the Nigerian economy.

The major factors contributing to the above unreliability and inefficiency in the power sector are:

(i) Frequent breakdown of generating plants and equipment due to inadequate repairs and maintenance;

(ii) Lack of foreign exchange to purchase needed spare parts on time

(iii) Obsolete transmission and distribution equipment which frequently breakdown

(iv) Lack of skilled manpower

(v) Inadequacy of basic industries to service the power sector.

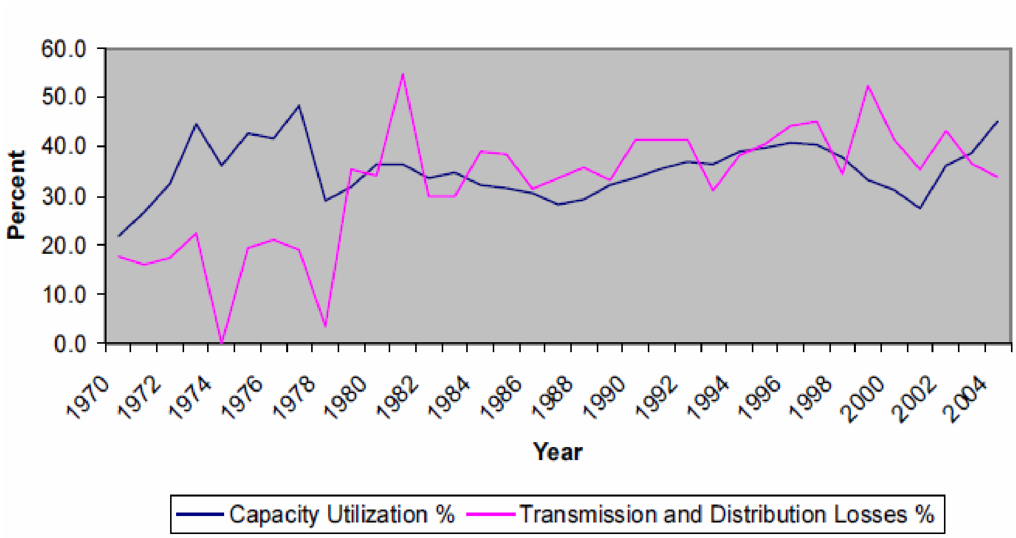

Figure 2. Indicator of Electricity Crisis in Nigeria 1970 to 2004 (Source: Iwayemi [6])

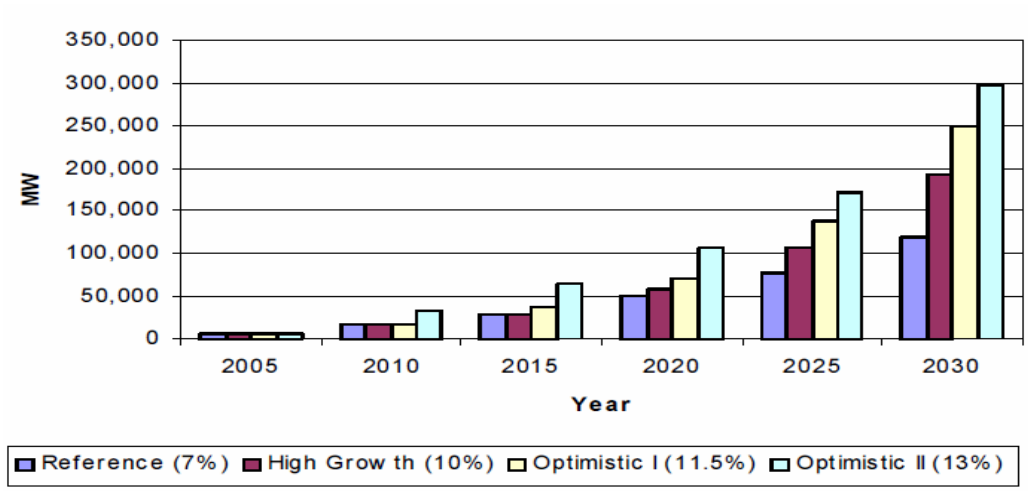

Figure 3. Electricity Demand Projection in Nigeria (Source: Sambo [2])

4. Decentralized Energy

Decentralized Energy (DE) is the production of electricity at or near the point of use, irrespective of size, fuel or technology. DE can be on-gird or off-grid and can be powered by a wide variety of fossil fuels [5]. It is an energy system that supplies an individual or small group of energy loads.

Currently, industrial countries generate most of their electricity in large centralized facilities, such as coal, nuclear, hydropower or gas powered plants. These plants have excellent economies of scale, but usually transmit electricity long distances.

Most plants are built this way due to a number of economic, health and safety, logistical, environmental, geographical and geological factors. For example, coal power plants are built away from cities to prevent their heavy air pollution from affecting the populace; in addition such plants are often built near collieries to minimize the cost of transporting coal. Hydroelectric plants are by their nature limited to operating at sites with sufficient water flow. Most power plants are often considered to be too far away for their waste heat to be used for heating buildings.

Low pollution is a crucial advantage of combined cycle plants that burn natural gas. The low pollution permits the plants to be near enough to a city to be used for district heating and cooling.

Distributed generation or Decentralized Energy (DE) is another approach. It reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used. This also reduces the size and number of power lines that must be constructed.

Typical distributed power sources in a Feed-in Tariff (FIT) scheme have low maintenance, low pollution and high efficiencies. In the past, these traits required dedicated operating engineers, and large, complex plants to pay their salaries and reduce pollution. However, modern embedded systems can provide these traits with automated operation and clean fuels, such as sunlight, wind and natural gas. This reduces the size of power plant that can show a profit.

What determines whether electricity generation is DE is not so much how electricity is generated rather where power is generated. DE technologies generate electricity where it is needed. Central generation on the other hand generates electricity in large remote plants and power must then be transported over long distances at high voltage before it can be put to use. It does not matter what technology one employs, whether it is used in connection with an existing grid or in a remote village, or whether the power comes from a clean renewable source or from burning fossil fuel: if the generator is 'on-site' it is DE. This means that, strictly speaking, DE could imply technologies that are not necessarily cleaner for the environment such as diesel generators without heat recovery. More often that not, however, DE is synonymous with cleaner electricity- indeed that is one of DE's main benefits.

Renewable DE is clean, and provides benefits not only to the individual investor but also to society on a whole. Like DE in general it can provide significant benefits: environmental, economic, efficiency, resource conservation, reliability and security.

What makes renewable DE distinct is that renewable DE technologies, as the name suggests, employ sources of energy to make electricity that can be replenished or that do not run-out over time. Sun and wind are perpetual and biomass is another word for fuel that comes from things that grow back including wood waste, agricultural residues etc.

However, just because a technology is renewable does not mean it can be considered DE. There is a strong argument that to use renewable electricity technologies optimally they should be used in a decentralized application but this is not always the case. Certainly renewable resources naturally occur in a decentralized manner: every year, the sun pours the equivalent of 19 trillion toe of energy onto the earth's surface a small fraction of which would be sufficient to meet all the world's energy demand (~9 billion toe per year) several times over. The energy the sun shines down however is not concentrated- rather spread evenly around the world. The case is similar with other renewable resources such as wind, hydro, geothermal and biomass. Renewable energy, therefore, can be used in DE applications and non DE applications but it is used optimally in DE applications.

DE can be broken into two main divisions:

(i) High efficiency cogeneration of heat and power, with capacities ranging from 1 kW to over 400 MW and which include reciprocating engines, gas turbines, steam turbines, fuel cells and micro turbines. Cogeneration, also known as combined heat and power or CHP, is a proven and reliable concept that recycles heat that is a byproduct of all combustion-based electrical generation and has been used widely in industry and buildings throughout the world.

(ii) On-site renewable energy systems and energy recycling technologies that capture otherwise wasted energy. These can include photovoltaic and biomass systems, on-site wind and water turbine generators, plus systems powered by gas pressure drop, exhaust heat from industrial processes, and low energy content combustibles from various processes.

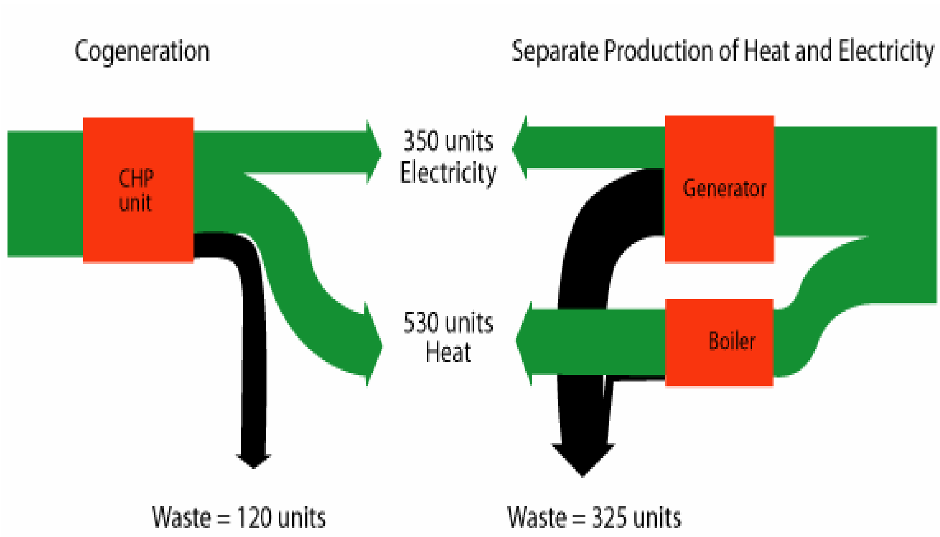

Figure 4. Cogeneration of Heat and Power (Source: WADE [5])

Figure 5. Comparison of Decentralized and Centralized Renewable Wind Technologies (Souce: WADE [5])

5. Electricity Supply Mix

Large hydro accounted for about 31.30% of grid electricity generation by 2005 while natural gas accounted for the balance of 68.30%. An analysis of the country's energy resource base clearly show that the nation stands to benefit immensely by ensuring that petroleum products are made to last for as many years to come as possible so they continue to serve as revenue earners and fuel the industrial sector for as many years as possible.

This can only be realized after the adoption of as many energy types as possible within the energy mix of the country in a Decentralized Energy (DE) manner. The clear and practical approach is to adopt the renewable energy sources of solar, biomass, wind energy and small-scale hydropower plants for as many applications as possible. This approach is supported by the fact that all or at least two renewable energy sources are available in all parts of the country, the technology for their use is mostly simple and for which the capacities exist; their use does not require the heavy financing and they are not associated with serious environmental implications.

Table 1. Nigeria Future Installed Electricity Generation Capacity by Fuel (%). (Source: Sambo [2])

Fuel Type	**2010**	**2015**	**2020**	**2025**	**2030**
Coal	0.0	9.9	13.8	15.3	15.6
Gas	78.6	48.5	53.5	53.0	59.0
Hydro	21.3	18.9	13.6	10.7	8.6
Nuclear	0.0	9.4	5.3	8.3	6.7
Solar	0.1	13.1	11.0	10.4	8.3
Wind	0.0	0.1	2.9	2.3	1.8

6. Conclusions

Nigeria is blessed with abundant resources of fossil fuels as well as renewable energy resources. There is the urgent need to encourage the evolvement of an energy mix that will emphasize the conservation of petroleum resources in such a manner that will lead to their continued exportation for foreign exchange earnings for as many years to come as possible. The adoption of renewable energy technologies in a Decentralized Energy (DE) manner especially for rural communities and in stand-alone applications will surely lead to reduced internal consumption of petroleum products.

The major advantages of the renewable energy technologies include the simplicity of the technologies, ease of maintenance as well as their enhanced environmental friendliness over fossil fuel systems. There is clear evidence of the use of renewable energy technologies at the moment. However there is the necessity to increase the use of the system especially for rural development.

In view of the apparent reluctance of local entrepreneurs to adopt the mature and proven renewable energy systems for mass production and subsequent commercialization there is need to actively promote the training of local craftsmen on the design, construction, operation and maintenance of appropriate energy end - use devices. After such training programmes soft loans could be made available to the craftsmen so they can commence the production and subsequent sale of the devices.

There is a growing worldwide acceptance that decentralized electric generation will reduce capital investment needs compared to central generation with its supporting transmission and distribution systems. In addition, decentralized generation can lower the cost of electricity, reduce pollution, reduce production of greenhouse gas, and decrease vulnerability of the electric system to extreme weather and militants attacks. While DE is unlikely to replace central power entirely, it is believed that the share of DE in global power generation will increase dramatically in coming years, with important benefits to all segments of the population and significant environmental benefits.

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