Emerging and Sustainable Energy Technologies*

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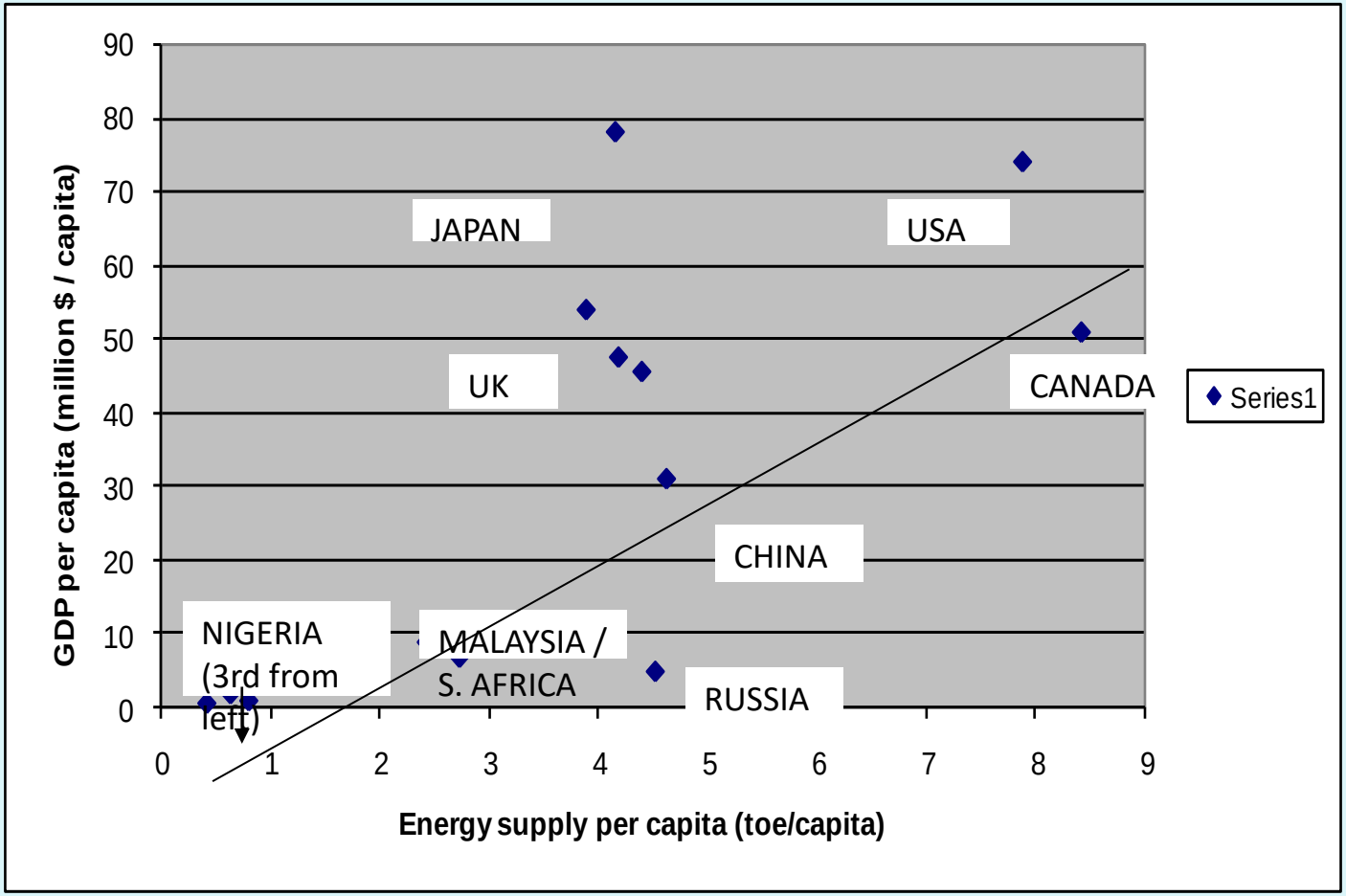
1. Introduction

- Energy is technically defined as the capacity to do work. From thermodynamics point of view, when work is done on or by a system, the state of the system changes. Thus, energy may be viewed as an agent of change or transformation.
- From social sciences point of view, the change or transformation derived from adequate energy supply in the economy manifests as economic growth and social development.
- This is usually depicted graphically by the plot of GDP/capita against Energy consumption/capita for various countries of the world and HDI Vs Energy consumption/capita.

1. Introduction ……Cont'd



Energy and Economy

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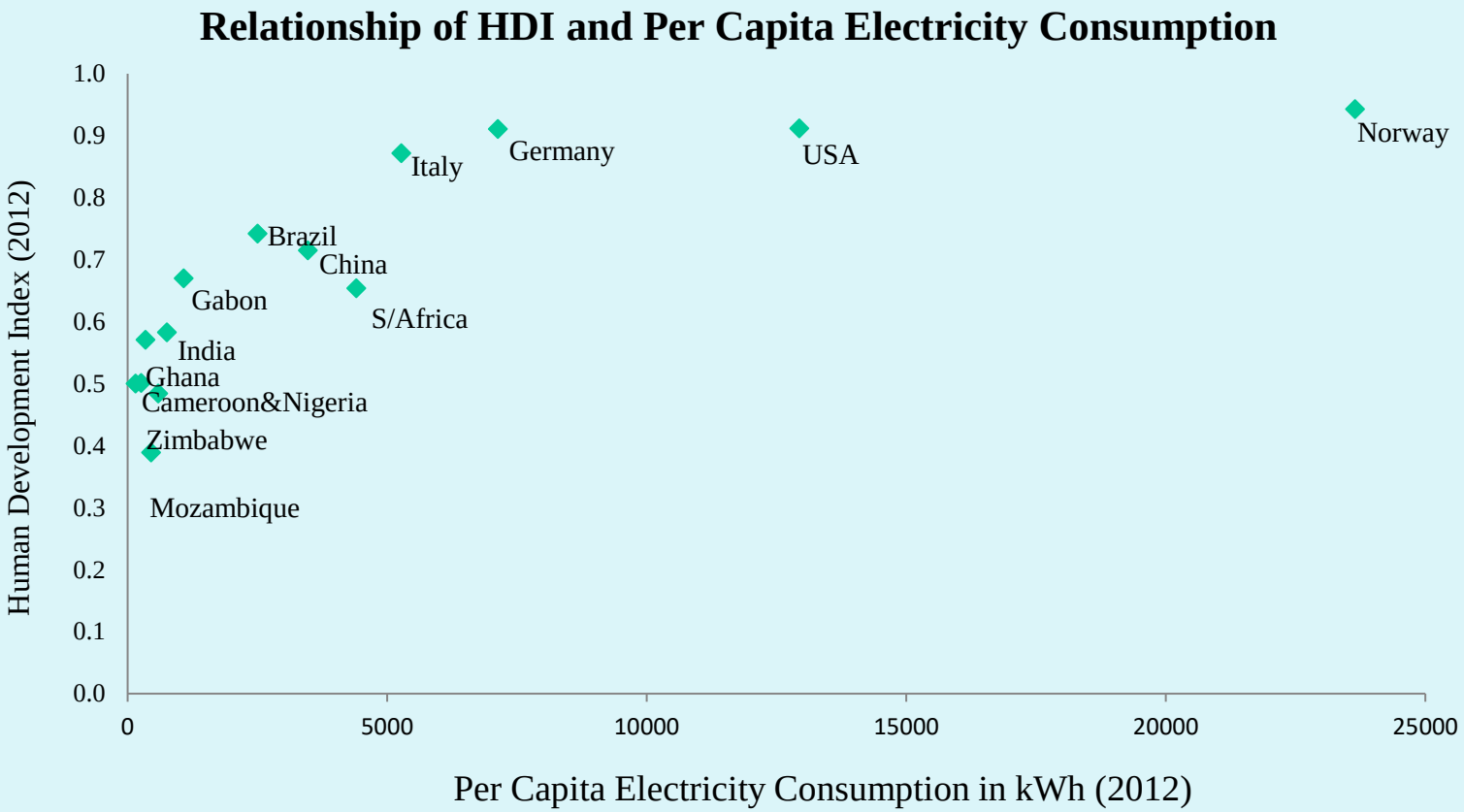
1. Introduction Cont'd…



Source: Human Development Report 2014 and IEA Key Energy Statistics 2014

1. Introduction ..... Cont'd

- Energy, however, exists in various forms: potential, kinetic, electromagnetic, mechanical, electrical, chemical etc; and one form may be transformed to another according to the laws of nature.

- An energy resource, in its basic form, may be processed into any of the following final energy forms:
  - Electricity
  - Fuels
  - Heat

1. Introduction ..... Cont'd

- Nigeria is endowed with fossil, nuclear and renewable sources of energy.

- Renewable energy is energy derived from energy source that can be regenerated naturally within a relatively short time frame. For example, solar radiation, wind, hydropower, biomass, geothermal, sea wave and tide.

- Unlike fossil type energy resource of crude oil, natural gas and coal, which have been formed over millions of years ago and are therefore depletable at any rate of consumption; renewable energy sources are more or less non-depletable due to its regenerative ability within relatively short time through natural process.

- They are also relatively environmentally friendlier and have good potentials for job creation especially in the rural areas.

1. Introduction ..... Cont'd

- Nuclear energy is from the atom, from where radiation is emitted through mainly atomic fission or fussion. It is a low carbon energy source.

- While renewable and nuclear energy are considered low carbon energy sources and therefore climate friendly; however, nuclear radiation safety poses a health and social concern.

- Sustainable energy systems are systems that allow development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

1. Introduction ..... Cont'd

- Nigeria's energy and indeed electricity demand is however projected to grow faster than the supply.
- This is a great challenge to the development of our country.

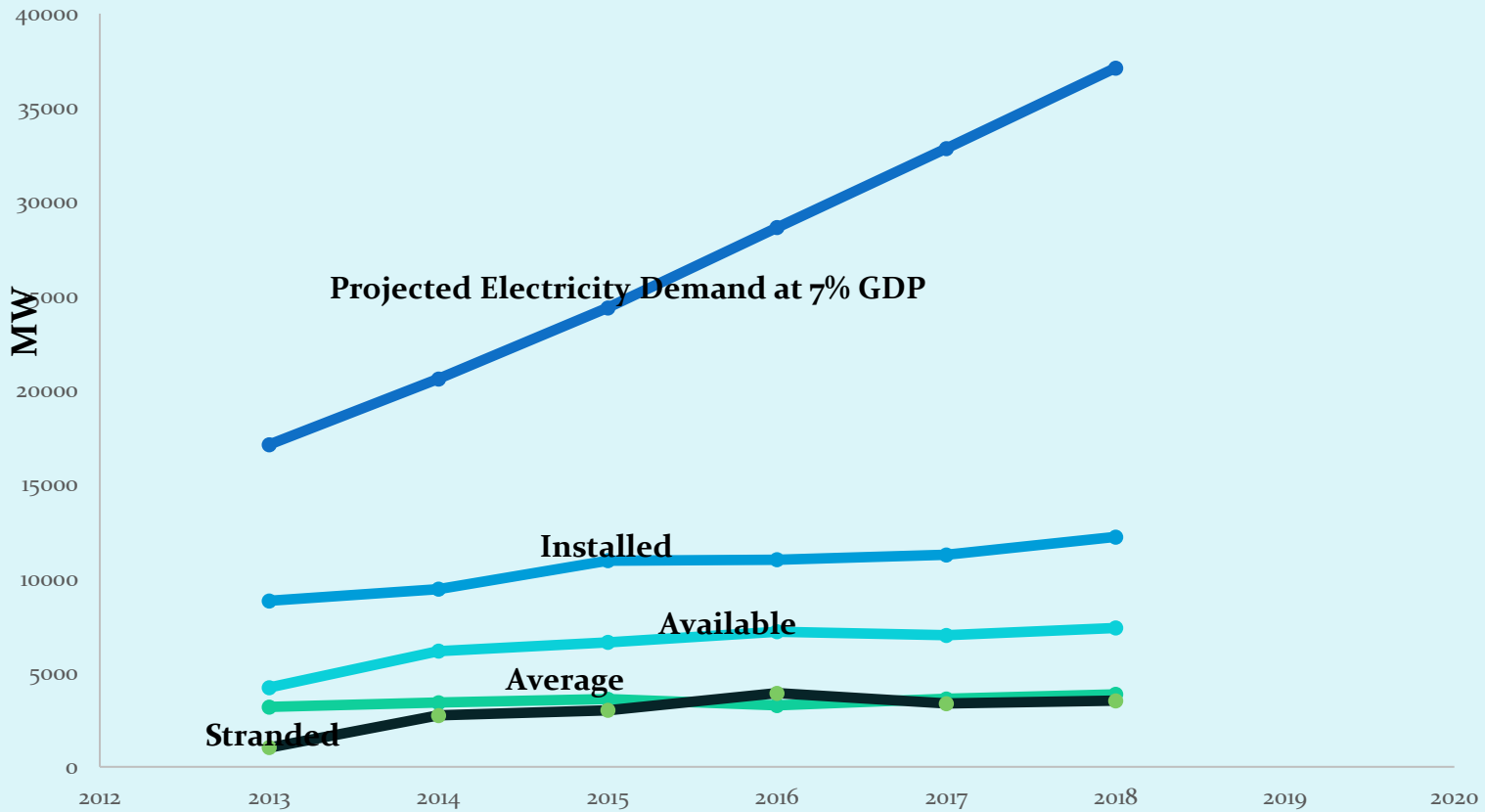


Fig.1 Electricity Demand and Supply Gap in Nigeria

Source: ECN, TCN and Gencos Heartbeat Vol.3 Issue 01

2. Energy Resources in Nigeria

a) Fossil Energy Resources and Nuclear Energy Sources

S/N	Resources	Reserves	Production (2018)	Domestic Utilization (2018)
1	Crude Oil	37.2billion barrels	0.853billion barrels	0.164billion barrels
2	Natural Gas	200 Tscf	2.84Tscf	90% : Utilized 10% : flared
3	Coal	2.7 billion tonnes	0	Negligible
4	Tar Sands	31 billion barrels of oil equivalent	0	18.25 million barrels
5	Nuclear	Yet to be quantified	0	30kW experimental nuclear reactor

Source: NNPC/ECN

2. Energy Resources in Nigeria

(b) Renewable Energy Resources

S/no	Resource		Reserve	Utilization Level
1	Large hydro power		11,250MW	1,972MW
2	Small Hydro power		3,500MW	64.2MW
3	Solar Energy		4.0kW/M²/day 6.5kW/M²/day	15MW solar PV stand-alone No solar thermal electricity
4	Wind		2-4m/s at 10m height	2x2.5KW electricity generator; 10MW wind farm in Katsina
5	Biomass	Fuel wood	11 million hectares of forest and woodlands	43.4 million tonnes of firewood/yr
		Municipal waste	- 18.3 million tonnes in 2005* & about 30 million tonnes/yr now	-
		Animal waste	- 243 million assorted animals in 2001	-
		Energy Crops and agric waste	- 28.2 million hectares of Arable land	8.5% cultivated

Source: REMP (2005)

* FM EMV

3. Overview of Sustainable and Emerging Energy Technologies

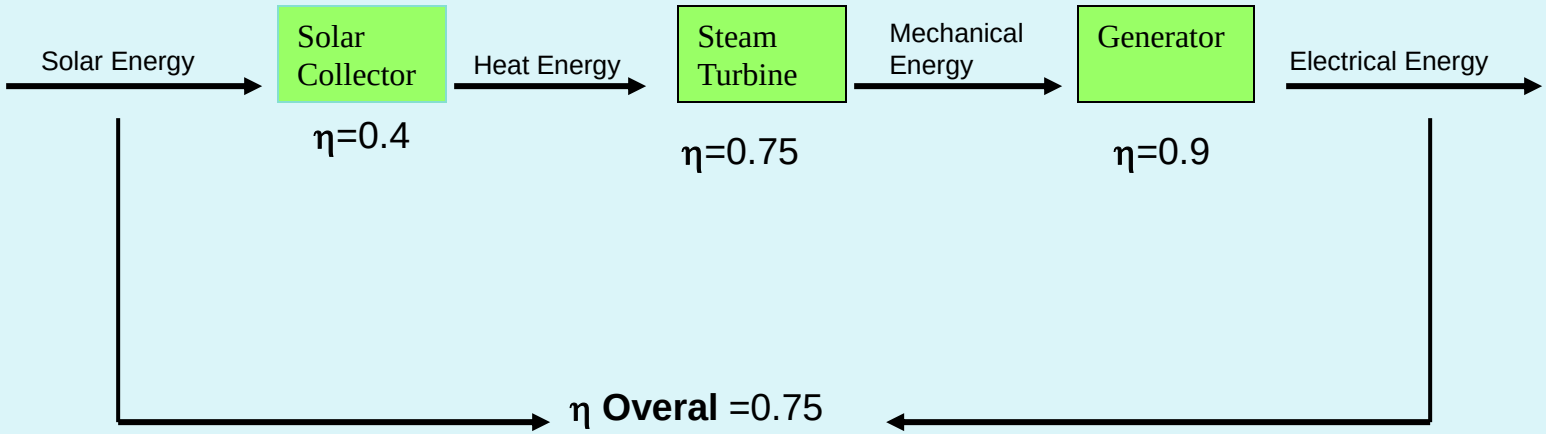
(a) **Solar Energy**:

- Exists in the form of electromagnetic radiation of wavelength ranging from 100μm and 1.0mm mainly ultraviolet, visible and infra-red radiations at the Earth's atmosphere.
- It may be transformed directly into heat using solar collectors or directly to electricity using solar PV cells.
- It is estimated that when 1% of Nigeria's land area is covered with a solar technology of 5% efficiency, about 333,480MW of electricity may be produced at about 26% capacity factor.
- This electricity generation capacity will be more than enough for the country, up to 2050, that will conveniently support double digit economic growth rate as envisioned by our principals.

3. Overview of Sustainable and Emerging Energy Technologies

(i) Solar Thermal Process:-

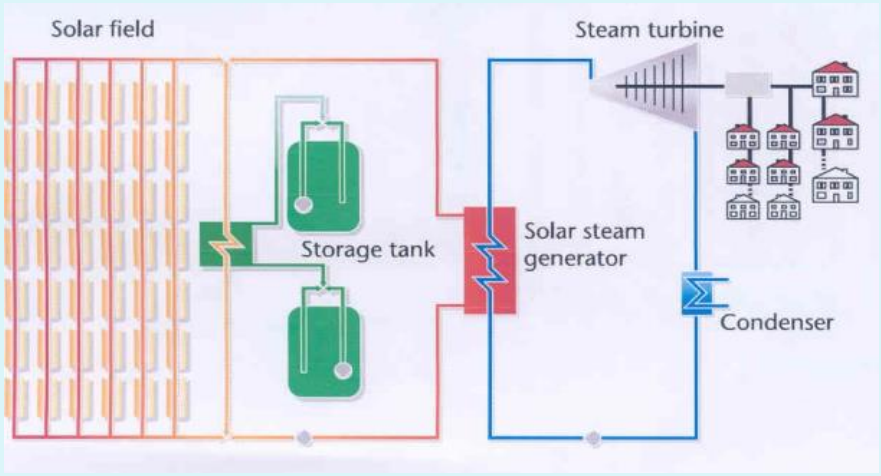
Solar Energy → Heat Energy → Mechanical Energy → Electrical Energy



3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd

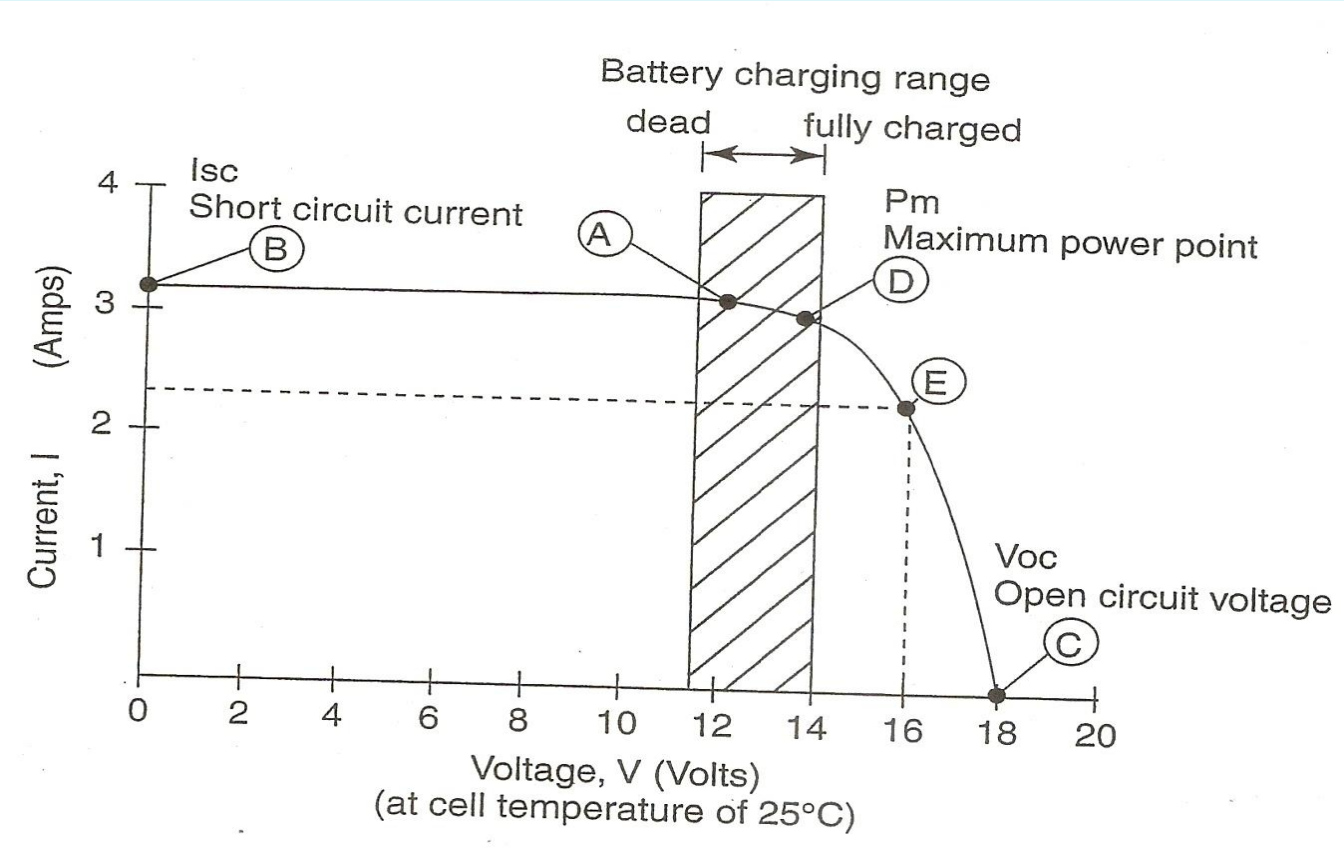
Solar thermal Plant in Spain (Heliostat)

50 MW Solar thermal Plant in Spain (Parabolic)



Rankine Cycle

(ii) Solar PV



Source: Mark Hankins (2010)

Figure 5. Typical Characteristics of Solar PV Modules

Solar PV

Commercially Available Solar Cell Module Types

Type of PV technology	Maximum cell efficiency	Typical commercial module efficiency	Notes
Crystalline Silicon			
Monocrystalline	24%	11–17%	Fully mature technology: 35% of world production (2007)
Polycrystalline	20%	11–15%	Fully mature technology: 45% of world production (2007)
Ribbon	19%	7–13%	Fully mature technology
Thin Film			
Amorphous Silicon	13%	4–8%	Initial degradation in performance
Multi-junction Amorphous Silicon	12%	6–9%	Similar to Amorphous Silicon Flexible
Cadmium Telluride	17%	7–8.5%	
Copper Indium Gallium Di-Selenide (CIGS)	19%	9–11%	
Organic (Dye)-type solar modules	12%	3-5%	Relatively uncommon
Other Types			
Hybrid HIT	21%	17%	Combined Amorphous Silicon and Crystalline

Source: Mark Hankins, 2010.

5. Energy Technologies for Sustainable Dev. In Nigeria..contd

Solar PV Systems

3kW solar PV mimi-grid in Talasse General Hospital, Balanga LGA, Gombe State (2013)

Solar PV powered Water Borehole in Abule Kajola, Akute, Ifo LGA, Ogun State (2013)

Solar PV Streetlight in Omiadio, Ido LGA, Oyo State (2013)

3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd

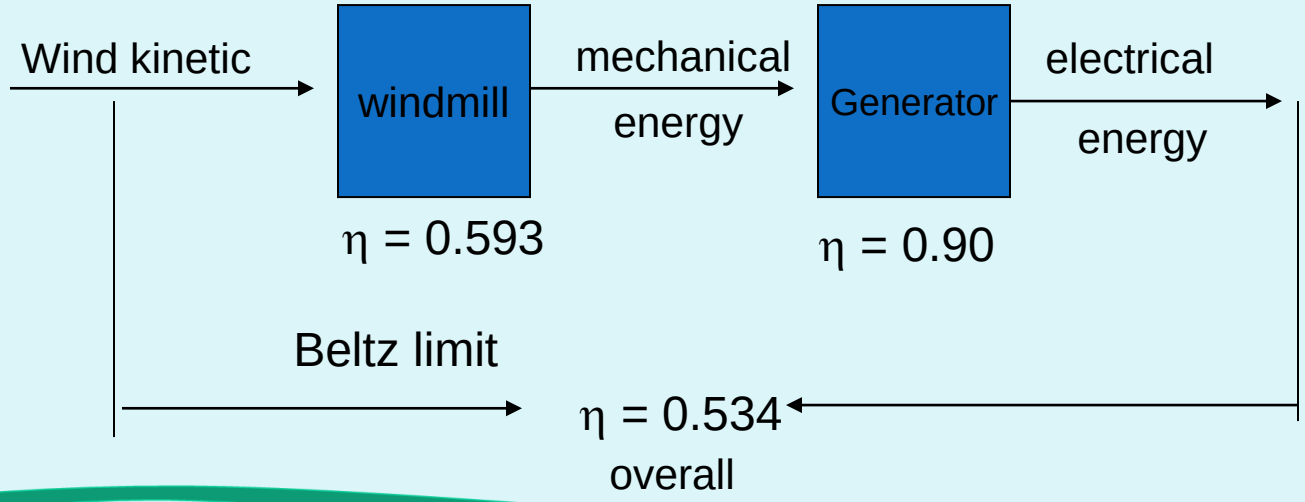
2.5 MW Solar PV, in Sal, Cape Verde
Commissioned October 1, 2010

5 MW Solar PV, in Praia, Cape Verde
Commissioned November 2, 2010

Source: ECREE (2011)

b) Wind Energy:

- Wind Energy exist in the form of Kinetic energy and the power therefrom varies with the cube power of the wind speed and the swept area of the rotor.
- The energy is converted into mechanical energy through aerodynamic propel or turbo modern principles. The mechanical power may be directly used to drive a water pump or an electric generator to produce electricity



3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd

150MW Osario Wind Farm, Brazil

305 MW Wind Farm at Zanfrana, along the Red Sea, Egypt

5kW aero generator in Sayya Gidan Gada, Sokoto State

3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd

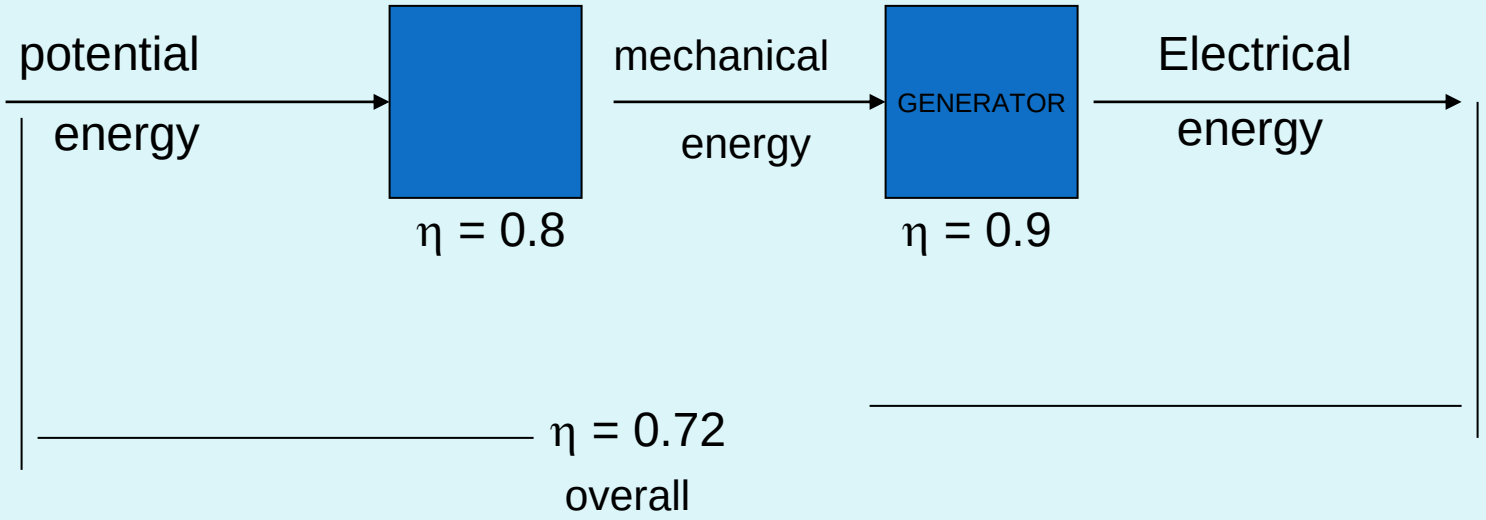
One of the 37 No 275kW Wind to Electricity Machines for the 10 MW Katsina Wind Farm

3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd

Drag Type wind Turbine for Water Pumping

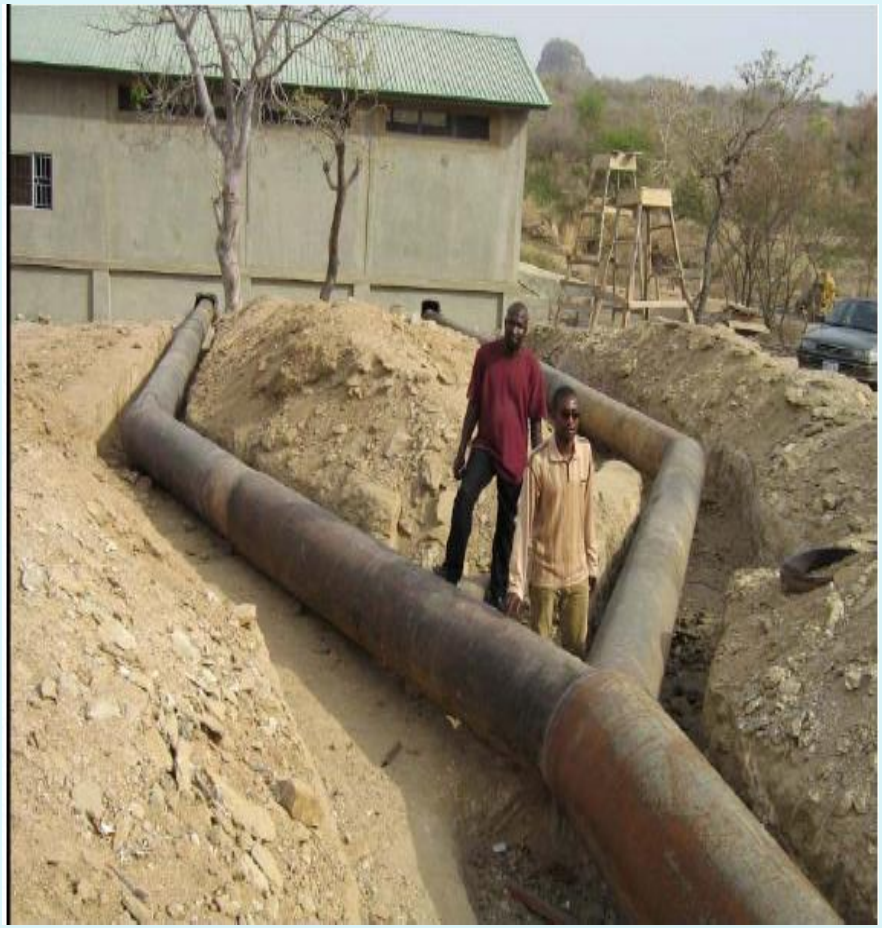
c) HYDRO ENERGY:

- It exist mainly in the form of potential energy, which is transformed into mechanical energy through turbo machinery principles



- It also, in hydro kinetics, converts the kinetic energy of flowing stream with mechanical energy and then to electricity.

3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd

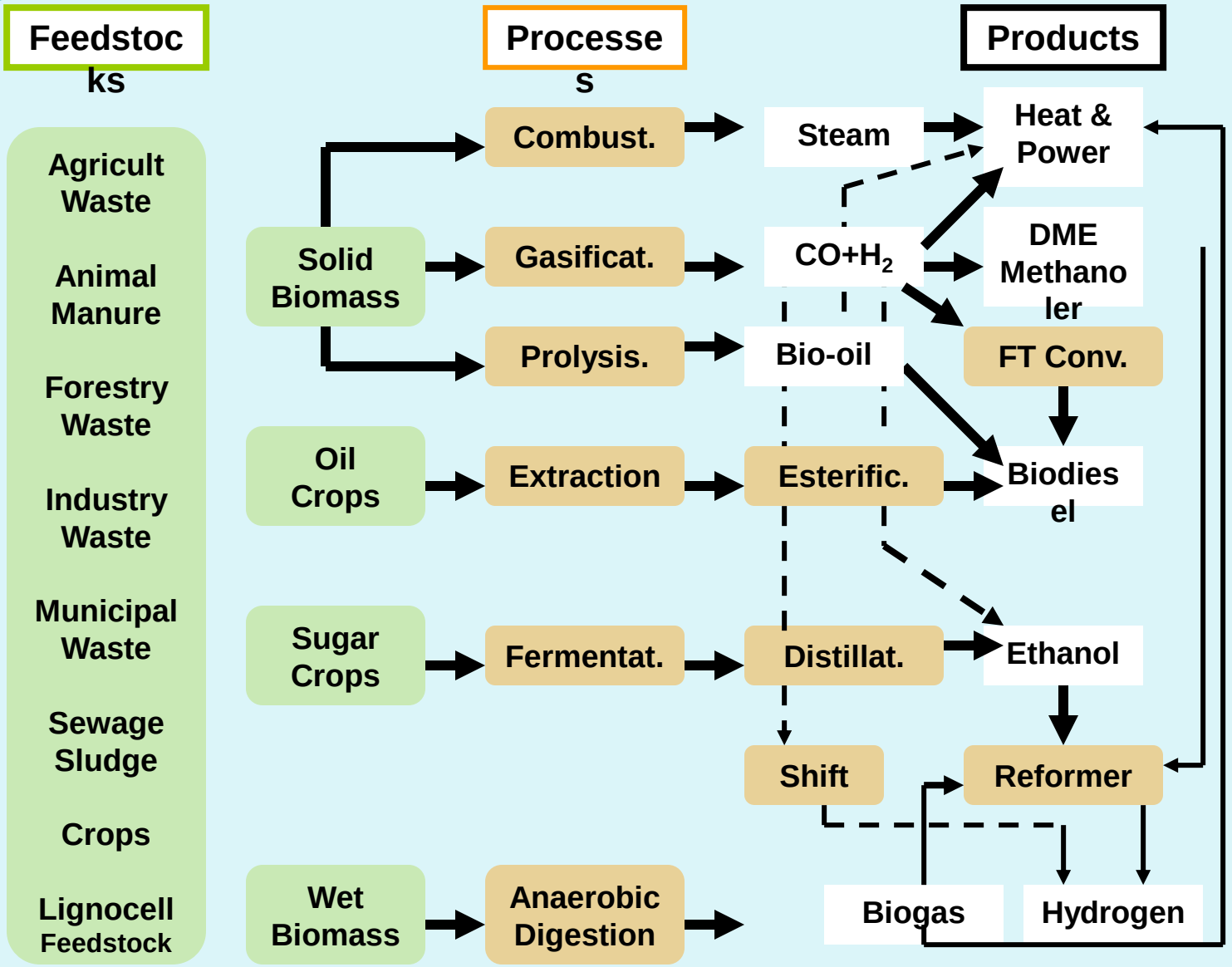


Penstock bifurcation into the 2 x 75 kW Francis Turbines at Waya Dam, Bauchi State

d) **BIOMASS**:

- Refers to non-fossil type matter of biological origin. The energy in biomass is in the form of chemical energy.
- Biomass Feed Stock mainly:
  - Fuelwood
  - Energy crops (1st generation feedstock mainly food crops and 2nd generation feedstock mainly non-food crops) from which bioethanol, biomethanol and biodiesel can be produced for heat, transportation and power generation.
  - Municipal solid waste, agric waste, forest waste, human waste, animal waste, woodchips, etc.

3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd



Biomass Conversion Paths

3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd

Sludge

Biogas Digester

Power House

Generating Plant

A 750 kW Plant for Biogas Electricity Generation in Germany

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e) Emerging Energy Technologies:

- Fuel cells: Electricity can be produced directly from the combination of hydrogen and oxygen in an electro chemical process in a fuel cell. Fuel cells can have efficiencies of up to 80%
- 2nd & 3rd generation biofuels feedstock: Biodiesel from non food feedstock e.g. Jatropha, Switch grass, Algae, non-food parts of crops (stems, leaves and husks)
- Ocean wave and tidal energy technology: Nigeria has a long coastal region where ocean waves and tidal energies can be transformed using turbines (horizontal axis or vertical axis) to generate electricity.
- Solar cells form organic substrates and nanotechnology with higher efficiencies.
- Thermionic Systems
- Thermoelectric Energy Systems

Thermionic Energy Conversion (TEC)

- Thermionic energy conversion (TEC) is the direct conversion of heat into electricity by the mechanism of thermionic emission, the spontaneous ejection of hot electrons from a surface.

- Although the physical mechanism has been known for over a century, it has yet to be consistently realized in a manner practical for large-scale deployment (David B. Go. Et al 2017)

Thermionic Energy Conversion (TEC)

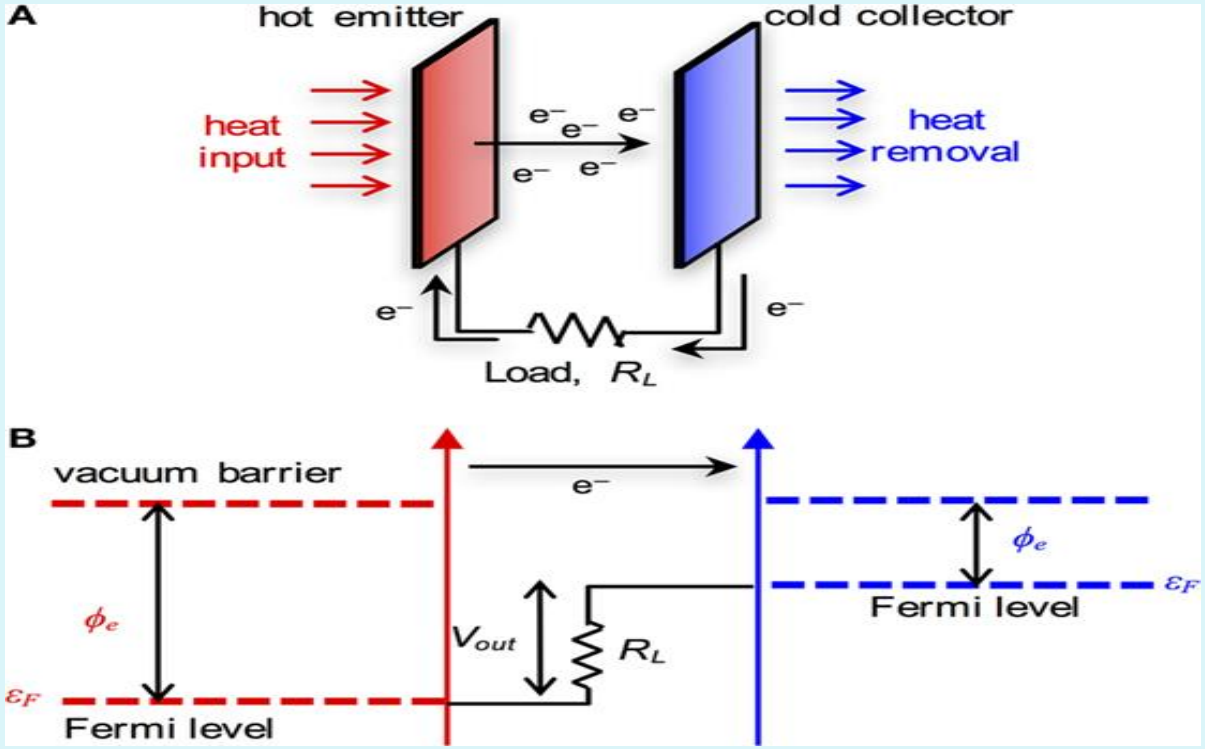


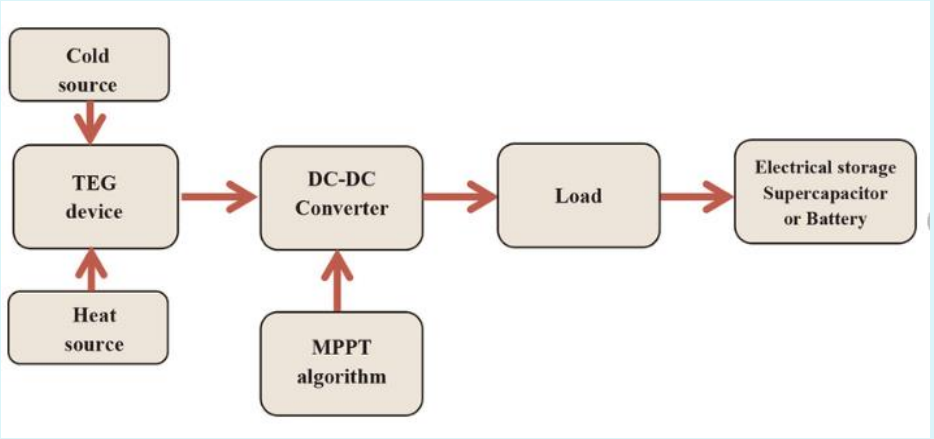
Figure (A) Schematic of the thermionic energy conversion (TEC) process. **(B)** Electromotive diagram showing electron energy levels during TEC.

Source: frontiersin.org

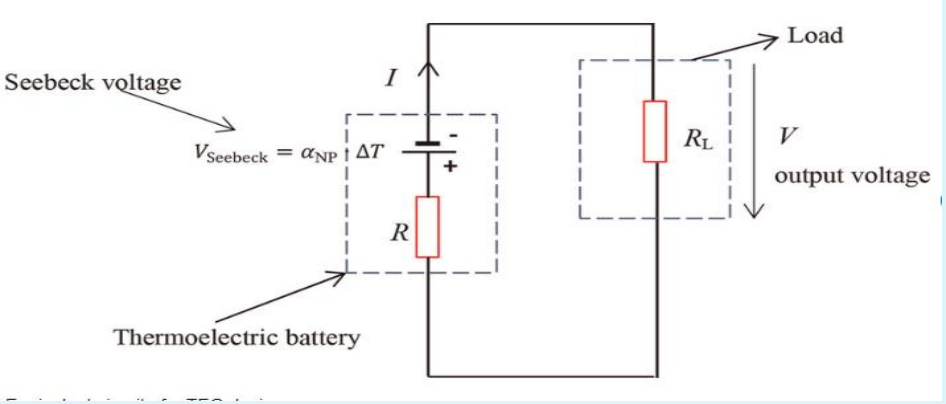
Thermoelectric Energy Conversion

- David Michael Rowe (2006) defined a thermoelectric converter is a solid-state heat engine in which the electron gas serves as the working fluid and converts a flow of heat into electricity.
- It has no moving components, is silent, totally scalable and extremely reliable.
- According to Gang Chen (2015), thermoelectric energy conversion exploits the Seebeck effect to convert thermal energy into electricity, or the Peltier effect for heat pumping applications.
- Thermoelectric devices are scalable, capable of generating power from nano Watts to mega Watts. One key issue is to improve materials thermoelectric figure- of-merit that is linearly proportional to the Seebeck coefficient, the square of the electrical conductivity, and inversely proportional to the thermal conductivity.
- Improving the figure-of-merit requires good understanding of electron and phonon transport as their properties are often contradictory in trends.

Thermoelectric Energy Conversion



Block diagram of a thermoelectric energy harvesting system



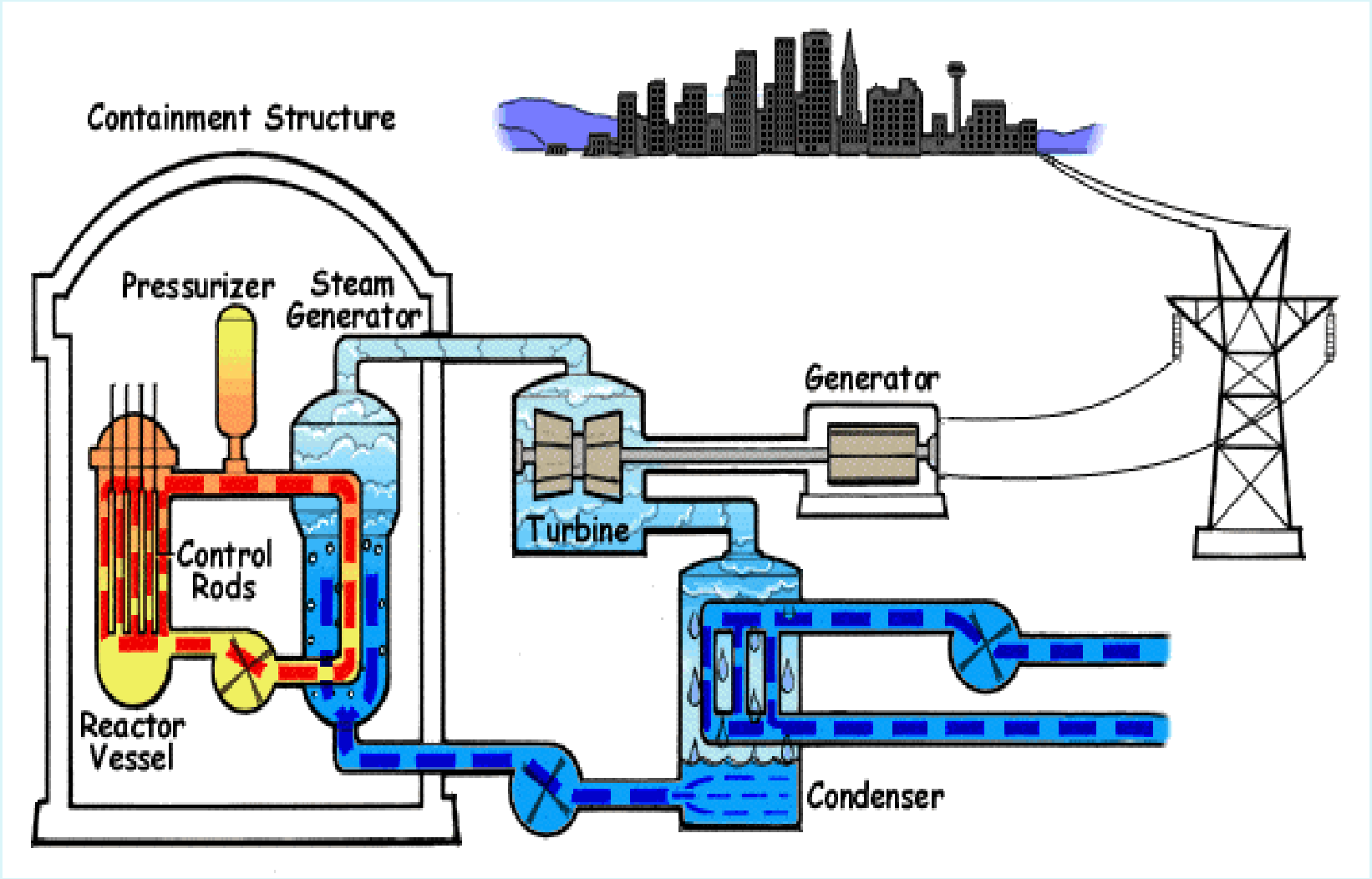
Equivalent circuit of a Thermoelectric Energy Generator (TEG) device

Source: Research gate.net

f) Energy Efficiency best Practices

- Use of efficient energy production and utilization (efficient power cycles and efficient energy appliances: combined cycles, improved fuelwood stoves, CFLs, LEDS, efficient R & A systems etc)
- Regular energy audits (detection of areas of energy wastages and rectification)
- Simple energy conservation practices (lighting controls, use of daylights, switching off energy appliances when not in use)

(g) Nuclear Power Plant



Typical PWR Power Plant System

3. Overview of Sustainable and Emerging Energy Technologies ..... Cont'd

414 MW Natural Gas Fired Power Plant, Geregu, Kogi State - NIPP

Global Electricity Cost in 2018

SOURCE	GLOBAL WEIGHTED-AVERAGE COST OF ELECTRICITY (USD/KWH) 2018	COST OF ELECTRICITY: 5TH AND 95TH PERCENTILES (USD/KWH) 2018	CAPACITY COST (USD/kW) 2018	CAPACITY FACTOR (%) 2018
Bioenergy	0.062	0.048–0.243	2,105	77.60
Geothermal	0.072	0.060–0.143	3,976	83.90
Hydro	0.047	0.030–0.136	1,491.9	46.80
Solar photovoltaics	0.085	0.058–0.219	1,210	18.00
Concentrating solar power	0.185	0.109–0.272	5,204	45.20
Offshore wind	0.127	0.102–0.198	4,353	42.50
Onshore wind	0.056	0.044–0.100	1,498.5	34.00

Source:IRENA, 2019

4. Conclusion

- Nigeria has varied energy resources that can be transformed into final energy of electricity fuels and heat, using appropriate technologies.

- Research and development on emerging energy systems as well as skills acquisition on these and older energy technologies need to be deepened.

Thank you
and
God Bless