GREEN SCIENCE AND TECHNOLOGY: AN INSTRUMENT FOR SUSTAINABLE ENERGY DEVELOPMENT*

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1. Introduction

I am indeed honoured and privileged to be invited to the 53rd Annual conference of Science Association of Nigeria being held in Usmanu Danfodiyo University in the historic city of Sokoto, the headquarters of Sokoto Caliphate to speak on Green Science and Technology.

- I gather that the conference has been dwelling on the general theme titled "Perspective of Science in the Mitigation of Climate Change and Security Challenge".
- "Green Science and Technology" to connote science and technology that are environmentally friendly.
- Indeed, climate change is a challenge to humanity which science and technology is essential in the identification of its causes as well as its mitigation and adaption.
- Climate change is primarily caused by the shift in natural balance of greenhouse gases (GHG) in the earth's atmosphere as a result of human activities.
- The major contributor to this imbalance is the energy sector, particularly the fossil fuel sub-sector, from where over 60% of the GHGs are emitted.

1. Introduction ……Cont'd

- It should be noted that GHGs in the atmosphere constitute heat trap with concomitant rise in temperature of the atmosphere and distortion of the climate parameters.
- The climate distortion could result into adverse living conditions such as desertification, flooding, soil erosion, migration, and general insecurity.
- Thus energy development must be such that greenhouse gas emissions are drastically reduced as a means of mitigating climate change to keep global warming at below 2°C above the pre-industrial revolution level and in line with Paris agreements and No. 7 of the Sustainable Development Agenda 2030.
- It is in the light of the above that I will discuss "***Green Science and Technology: An instrument for Sustainable Energy Development.***"

2. Green Science and Technology

- May I refresh your memories by defining the concept of Greening, Science and Technology.
- The word Science is derived from Latin word “Scentia” which means “knowledge”.
- In one of the several definitions, it is expressed as the observation, identification, experimental investigation, and theoretical explanation of natural phenomena and its application by humanity.
- Technology on the other hand is the application of scientific knowledge for practical purposes, to improve the standard of living of humanity.
- It is the collection of techniques, skills, methods, and processes used in the production of goods or services or in the accomplishment of objectives.
- Science may be broadly classified into:

2. Green Science and Technology .....Contd

- Natural science: description, prediction, and understanding of natural phenomena, based on empirical evidence from observations and experimentation. It can further be classified into;
- Life/Bio sciences, i.e. study of living matter e.g. e.g. Biology, Chemistry, Botany, Microbiology, etc.
- Physical Science, i.e. study of non-living matter e.g. physical chemistry, physics, astronomy, geology, etc.
- Social Sciences i.e. study of human society and social relationships e.g. Economics, Sociology, Business Administration, political science, etc.
- Applied Sciences, e.g. Engineering, Medicine, Biochemistry, Pharmacy, Agriculture, etc.

2. Green Science and Technology .....Contd

- As earlier indicated, the word greening in this context refers to environmental friendliness or climate friendly.
- Consequently green science and technology implies science and technology that promote climate friendliness or environmentally benignness.
- Energy has over the years, since the industrial revolution, promoted economic and social development.
- However, science has shown that the planet earth, where humans live on, is getting warmer and warmer since the first industrial revolution of the 18^{th}-19^{th} Century;
- Global warming was primarily due to exploitation, processing and utilization of fossil fuel energy resources that was driving development

2. Green Science and Technology .....Contd

- It was in 1987 that the World Commission on Environment and Development (WCED) in the Brundtland Report on "Our Common Future" came up with a modern concept of development, referred to as Sustainable Development, which articulates the needs of the present without compromising the ability of future generations to meet their own needs.
- The challenge of energy trilenma; the need for a balance between energy, economy and environment therefore evolved.
- In 2015, COP 21 was held in Paris, where the world agreed to reduce its emissions such that the earth's temperature does not rise beyond 2C above the pre-industrial level by 2030.
-

2. Green Science and Technology ……Contd

- Nigeria pledged to reduce its GHG emissions by 20% unconditionally and 45% conditionally by 2030; through zero natural gas flare out from its oil wells, 13 GW of off-grid electricity from Renewables, 30% energy efficiency at 2% per annum by 2030, smart agriculture and land use, and adoption of mass transportation.

- To achieve these plans, goals and targets, green science and technology is imperative.

- The ones relevant to the energy sector will be discussed.

2.3. Energy Resources in Nigeria

Table 1: Fossil Energy Resources and Nuclear Energy Sources

S/N	Resources	Reserves (2017)	Production (2017)	Domestic Utilization (2017)
1	Crude Oil	36.97* billion barrels	0.661 billion barrels	0.145 billion barrels
2	Natural Gas	199.09 Tscf	2.94 Tscf	88% : Utilized 12% : 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

2.3. Energy Resources in Nigeria

Table 2: Renewable Energy Resources

S/N	Resource		Reserve	Utilization Level
1	Large hydro power		11,250MW	1,900MW
2	Small Hydro power		3,500MW	64.2MW
3	Solar Energy		4.0 kWh/m²/day 6.5kWh/m²/day	About 100MW solar PV stand-alones; 1 MW grid connected PV; No solar thermal electricity
4	Wind		2-4m/s at 10m height	2x2.5KW electricity generator in Sokoto; 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	- 72 million hectares of Agricultural land	28.2 million hectares of Arable land only 8.5% is cultivated

Source: REMP (2005) * FM EMV

4. Green Energy Technologies

- Green energy technologies are technologies that enable the production of electricity, fuel and process heat from renewables as well as energy efficient systems and products and innovation of energy conservation best practices.

4. Green Energy Technologies ……. Contd

Solar Energy:

- Solar energy is produced through thermo nuclear process in the sun.
- It exist in the form of electromagnetic radiation 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 vision 20:2020.

4. Green Energy Technologies ……. Contd

- Figure 1 and 2 show photographs of solar thermal power plants in Spain, whereas Fig. 3 shows the basic flow diagram for the power plants in Fig. 1 and 2 operating under the basic thermodynamic power cycle known as the Rankine cycle.
- Fig 4 is a typical performance of a solar thermal collector that operates a solar thermal power plant.
- For the direct Conversion of solar energy into electricity, a solar cell is employed with its I-V characteristics as shown in Fig. 5.
- Table 3 shows the efficiencies of some commercial solar cells and modules therefrom.
- Figs 6,7, and 8 show photographs of the deployment of solar PV technology for community power supply, street lighting and clean water supply for drinking and sanitation in Nigeria.

4. Green Energy Technologies ……. Contd

Fig. 1: Solar thermal Plant in Spain (Heliostat)

4. Green Energy Technologies ..... Contd

Fig. 2: MW Solar thermal Plant in Spain (Parabolic)

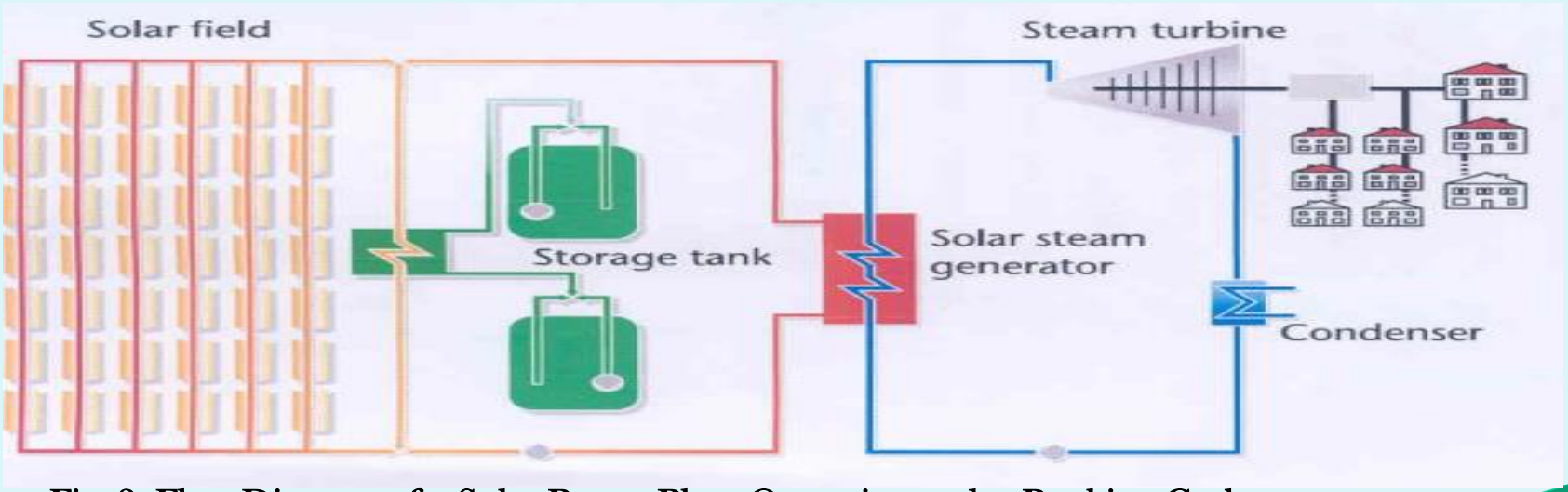

Fig. 3: Flow Diagram of a Solar Power Plant Operating under Rankine Cycle

4. Green Energy Technologies ..... Contd

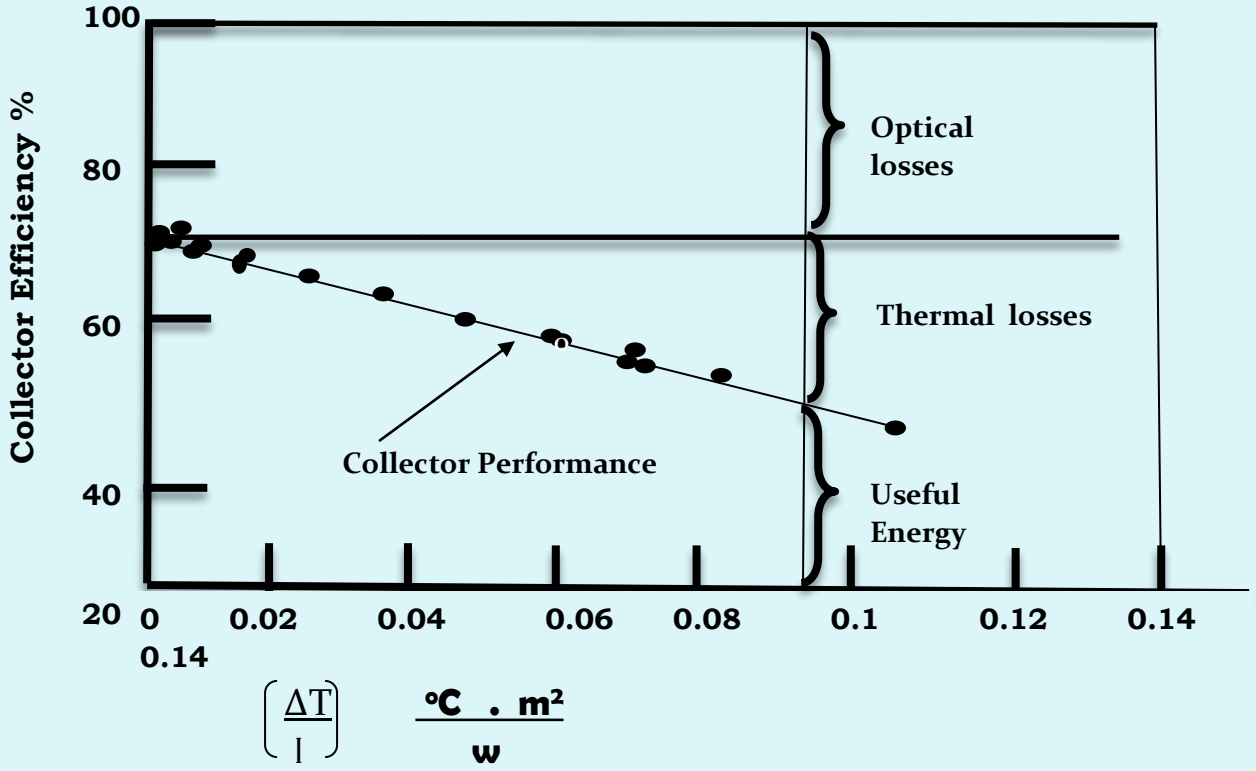

Fig. 4: Typical Performance Characteristics of a Solar thermal Collector

4. Green Energy Technologies ……. Contd

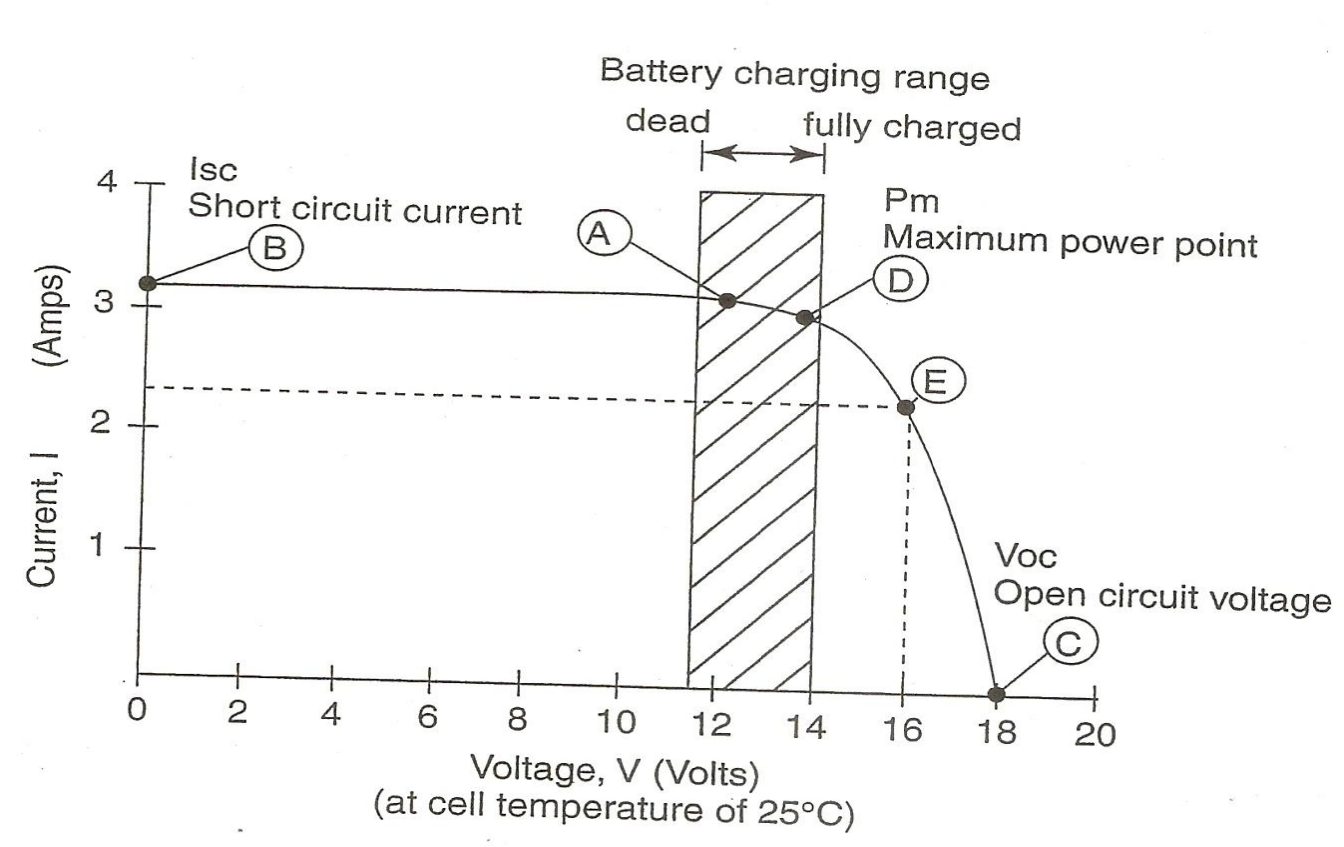

Figure 5. Typical Characteristics of Solar PV Modules

Source: Mark Hankins (2010)

4. Green Energy Technologies ……. Contd

Table 3: 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.

4. Green Energy Technologies ..... Contd

Fig. 6: Solar PV Mini-Grid in a Village in Sokoto, Sokoto State

Fig.7: Solar Street Lighting in Uyo, Cross River State

4. Green Energy Technologies ..... Contd

Fig. 8: Solar Water Pumping for Students in Sokoto, Sokoto State

4. Green Energy Technologies ……. Contd

- Nigeria pledged to reduce its GHG emissions by 20% unconditionally and 45% conditionally by 2030; through zero natural gas flare out from its oil wells, 13 GW of off-grid electricity from Renewables, 30% energy efficiency at 2% per annum by 2030, smart agriculture and land use, and adoption of man transportation.

- To achieve these plans, goals and targets, green science and technology is imperative. The ones relevant to the energy sector are hereby discussed.

4. Green Energy Technologies ……. Contd

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.
- Fig. 9 depicts typical performance characteristic of a lift type wind turbine.
- Fig 10 shows the flow diagram of harnessing wind energy to electricity; whereas Figs. 11, 12 and 13 shows photographs of some wind mill installations in Nigeria.

4. Green Energy Technologies ……. Contd

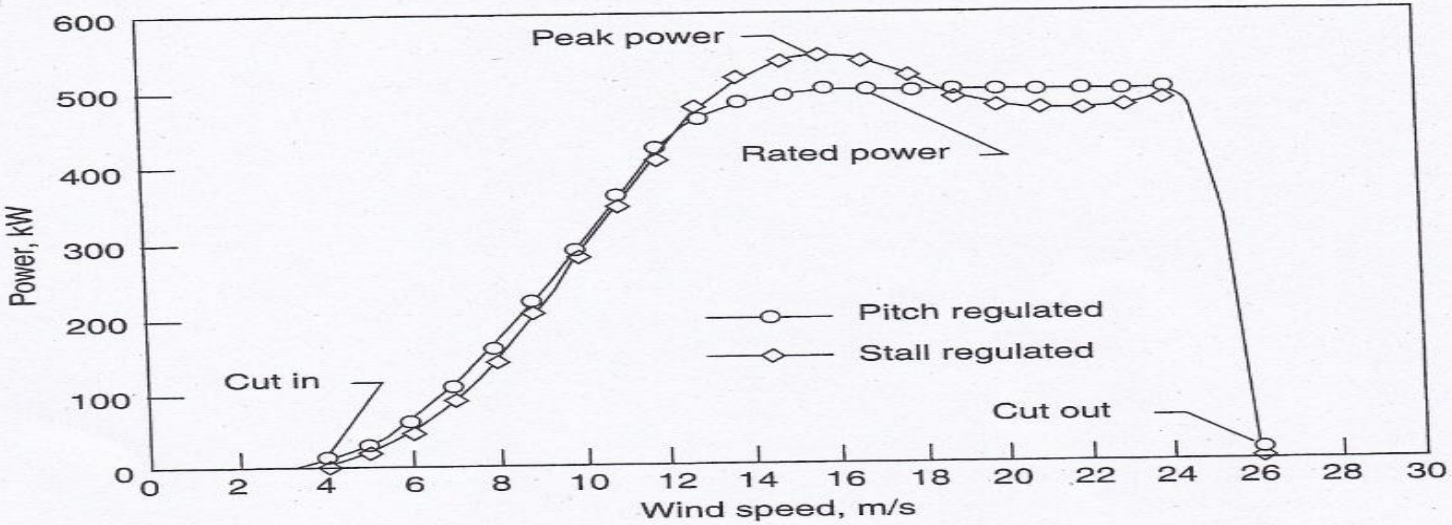

Fig . 9: Flow Typical Performance Charateristic of Wind Turbine

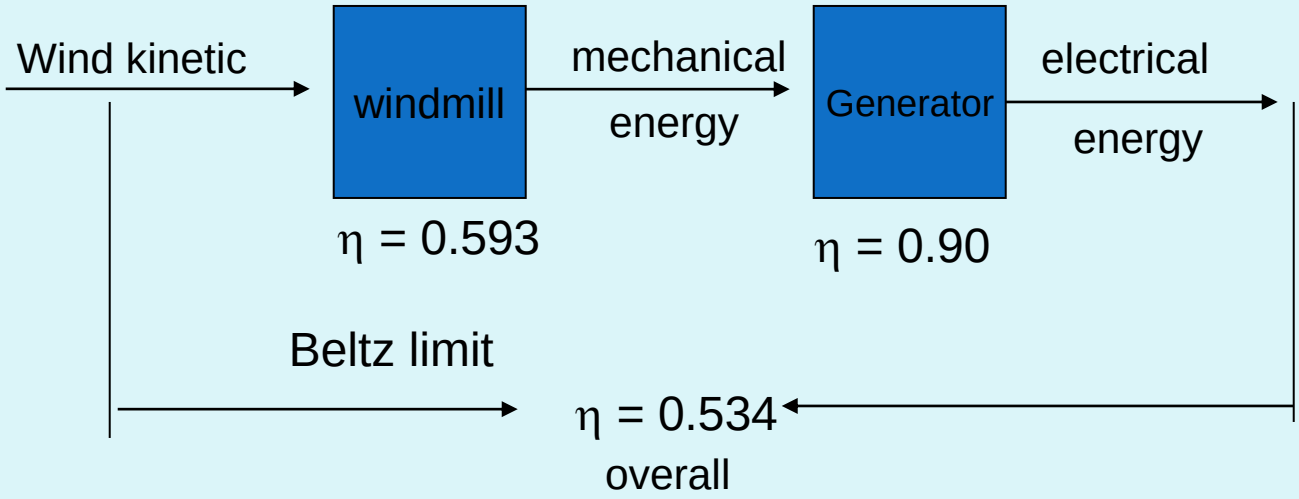

Fig . 10: Flow Diagram of Harnessing Wind Energy to Electricity

4. Green Energy Technologies ..... Contd

Fig. 11: 5kW aero generator in Sayya Gidan Gada, Sokoto State

4. Green Energy Technologies ……. Contd

Fig. 12: One of the 37 No 275kW Wind to Electricity Machines for the 10 MW Katsina Wind Farm

4. Green Energy Technologies ……. Contd

Fig. 13: Drag Type Wind Mills for Water Pumping in Rural Areas

c) **Hydro Energy:**

- It exist mainly in the form of potential energy, which is transformed into mechanical energy through turbo machinery principles.
- Fig. 14 shows the flow diagram of the conversion of hydropower to electricity whereas Fig. 15 show photograph of a SHP plant in Bauchi State

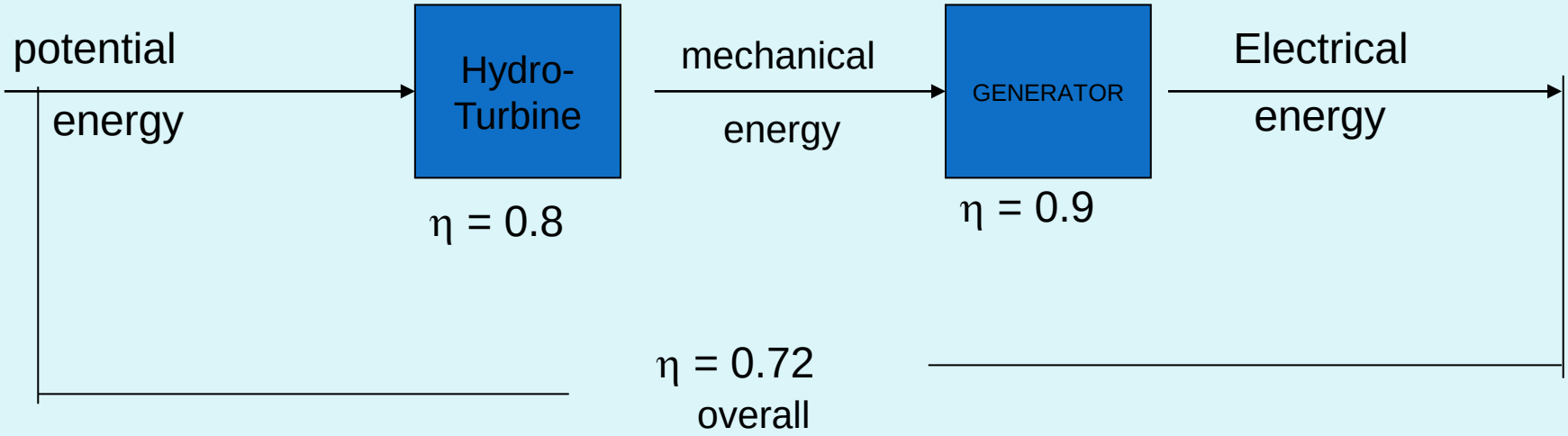

Fig . 14: Flow Diagram of Hydropower to Electricity

4. Green Energy Technologies ..... Contd

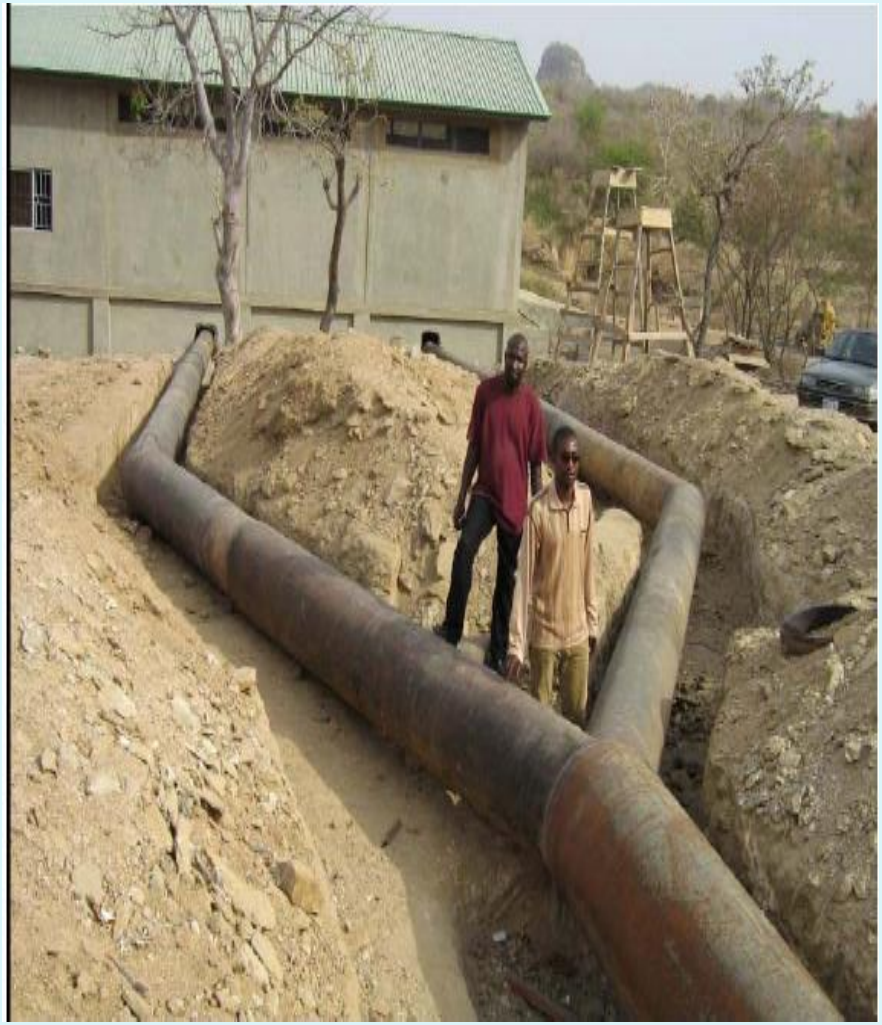

Fig. 15: Penstock bifurcation into the 2 x 75 kW Francis Turbines at Waya Dam, Bauchi State

4. Green Energy Technologies ……. Contd

(d) BIOMASS:

- Refers to non-fossil type matter of biological origin.
- Biomass is said to be carbon neutral and so climate friendly.
- The energy in biomass is in the form of chemical energy. Biomass Feed Stock are 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.
- Fig. 16 shows the energy conversion flow paths from various biomass resource to final energy; whereas Fig. 17 is the photograph of a typical anaerobic biogas plant from agric waste in a German agrarian community.

4. Green Energy Technologies ……. Contd

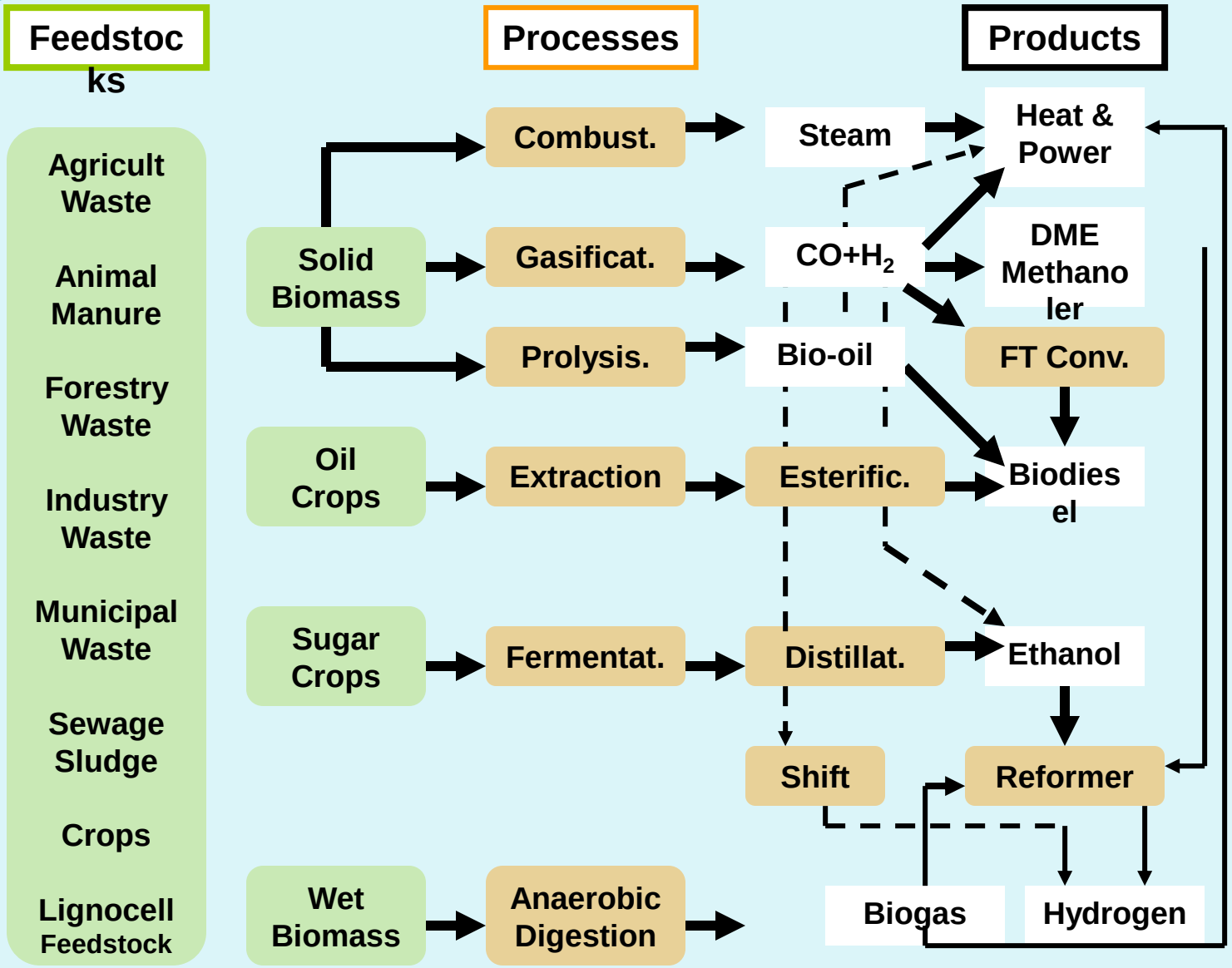

Fig. 16: Biomass Conversion Paths

4. Green Energy Technologies ..... Contd

Sludge

Biogas Digester

Power House

Generating Plant

Fig. 17: A 750 kW Plant for Biogas Electricity Generation in Germany

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4. Green Energy Technologies ……. Contd

e) Emerging RE Technologies:

- Fuel cells: Electricity can be produced directly from the combination of hydrogen and oxygen in an electro chemical process in a fuel cell with steam and not CO_2 as exhaust.
- It is therefore climate friendly.
- Fuel cells can have efficiencies of up to 80%.
- There are also 2nd & 3rd generation biofuels feedstock for biodiesel production from non food feedstock e.g. Jatropha, Switch grass, Algae, non-food parts of crops (stems, leaves and husks).
- Climate friendly energy can also be produced from Ocean wave and tide.
- 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 from organic substrates and nanotechnology with higher efficiencies are also emerging green technologies.

f) Nuclear Power

- Nuclear power is derived mainly from fission of nuclear fuel, mainly Uranium-235 in a reactor core, where energy available from the controlled fission process is captured as heat that is transferred to working fluids that are used to generate electricity.
- For example, 1 gram of U-235 fissioned will generate about 1MW day of energy.
- Nuclear power technology may be considered green since GHGs are hardly produced during its operation
- Fig. 18 shows the flow diagram of a nuclear power plant.

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

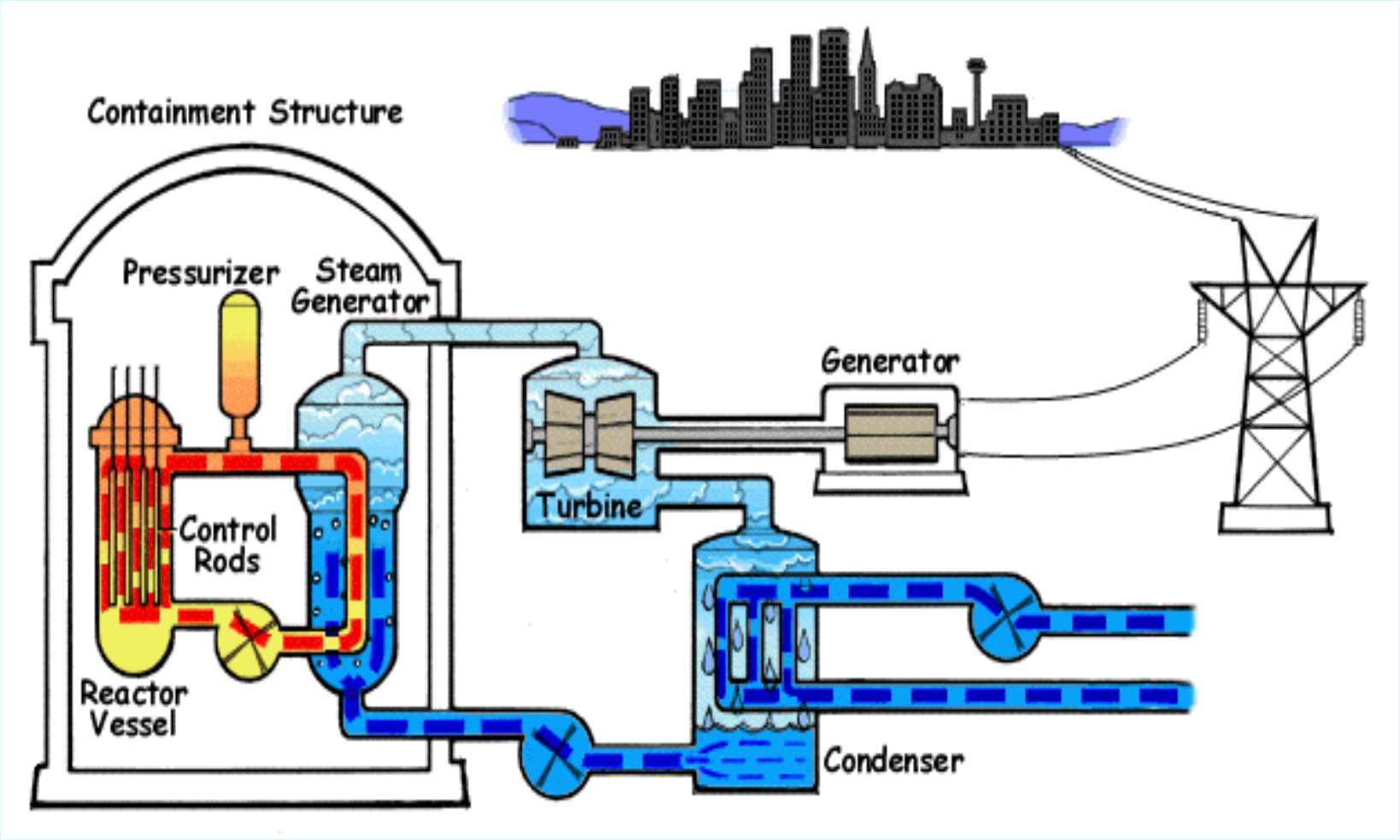

Fig. 18: Flow Diagram of a Nuclear Power Plant

g) Natural Gas Power Plant

- Natural gas, mainly methane (CH_4) is itself a GHG.
- The use of natural gas indeed emits other GHGs, mainly carbon dioxide (CO_2).
- However, because it is the only hydrocarbon fuel compound with the least carbon atom; and thus, produces the least quantity of CO_2 on combustion, it may be considered a climate friendly fuel relative to other hydrocarbon fuels.
- Fig. 19 shows photograph of a typical natural gas fired power plant in Nigeria, whereas Fig. 20 depicts the simple flow diagram of a basic open-cycle gas power plant operating under Braython thermodynamic cycle.
- More of these power plants would enable the NDCs to be met by eliminating gas flaring from our oil wells.

4. Green Energy Technologies ..... Contd

Fig. 19: 414 MW Natural Gas Fired Power Plant, Geregu, Kogi State - NIPP

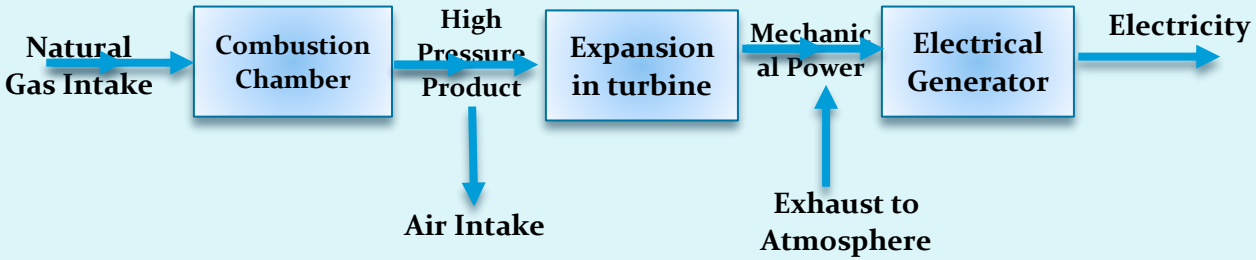

Fig. 20: Simple Flow Diagram of Gas Power Plant

4. Green Energy Technologies ……. Contd

h) Energy Efficiency Best Practices

- Use of efficient energy production and utilization (efficient power cycles and efficient energy appliances reduce energy demand through combined cycles, improved fuelwood stoves, CFLs, LEDS, efficient R & A systems etc.)
- Regular energy audits through detection of areas of energy wastages and rectification and simple energy conservation practices such as lighting controls, use of daylights, switching off energy appliances when not in use, etc. are greening measures that mitigate climate change

5. Conclusion

- Nigeria has varied climate friendly energy resources that can be transformed into final energy of electricity, fuels and process heat using appropriate technologies to mitigate climate change.
- Renewable energy, energy efficiency and conservation as well as other low carbon technologies are instruments necessary to mitigate global warming and its adverse consequences.
- Research and development as well as skills acquisition and continuous advocacy on these green scientific methods and technologies need to be deepened.

Thank you
and
God Bless