Renewable Energy Technology

Faculty of Engineering
American International University-Bangladesh

Renewable Energy Technology

Course Outline

- **Introduction to Renewable Energy Technologies**
  - *Current Energy Scenario*
- **Solar Thermal**
  - *Solar Fundamentals*
  - *Solar Radiations*
  - *Geographical and Annual calculation of Solar Insulations*
  - *Different types of tracking arrangement*
  - *Solar Thermal Technology*
  - *Various types of solar energy applications*
  - *Solar Thermal power plants*
- **Solar PV Cell**
  - *Solar Photovoltaic Technology*
  - *PV cells and its classifications*
  - *Maximum Power Point (MPP)*
  - *Design of Solar Module*
  - *Application of Solar PV*
- **Wind Energy**
- **Biomass Energy**
- **Geothermal Energy**
- **Energy Storage**

"Design for tomorrow because, the day after tomorrow may be too late!!"

Midterm

Final term

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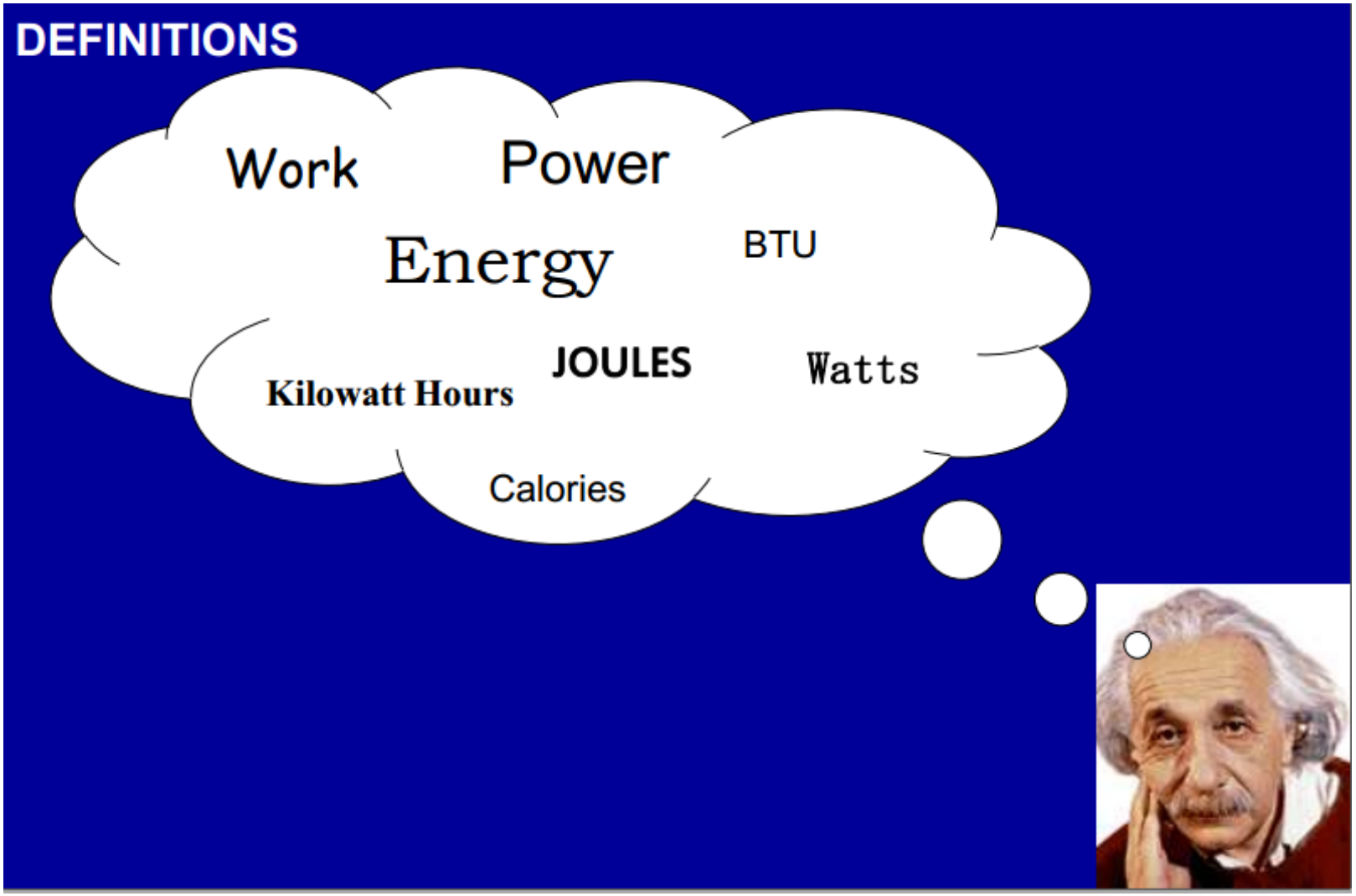

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Definitions

Work

- In the physics sense "Work" is about moving an object against a resisting force
- *Work is done when an object is made to move in the direction of an applied force.* This is expressed as:

Work = Force × Distance, where: F (N) = mass (kg) × acceleration (ms^{-2})

The unit of work is Joules [J]

- Joule is defined as the energy supplied by a force of one Newton in causing movement through a distance of one meter

Example:

Lifting an object of mass, M, by a distance h, from the ground

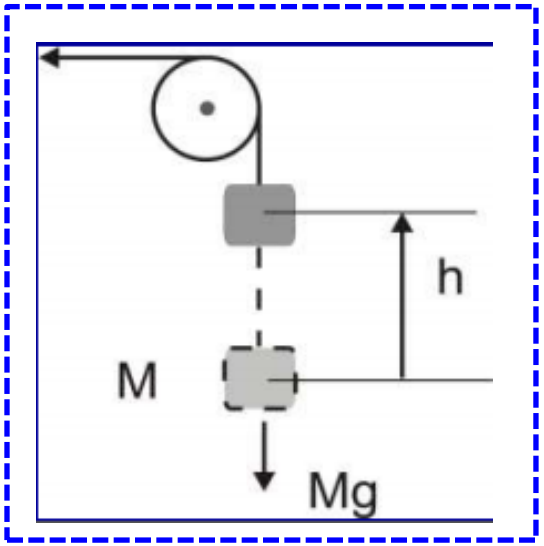
Work done = M × g × h

Force = M × g (Newtons, N)

Distance, h : (meters, m)

Hence, Work = N × m (Joules, J)

[J] = [N] [m]



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Definitions

Energy

- Energy is defined as the *capacity or ability to do work*.
- Energy describes consumption and harnessing of resources.
- The unit of energy is also Joules [J].

Examples of forms of Energy:

- Thermal Energy (heat)
- Chemical Energy (in fuels or batteries)
- Kinetic Energy (in moving substances)
- Electrical Energy
- Gravitational Potential Energy

Renewable Energy Technology

Definitions

Power:

- Power is the rate at which energy is converted from one form to another, or transferred from one place to another.

- It is the rate per second at which energy is transformed, consumed or produced
- Power is measured in Watts [W]
- [1W] = [1J] / [s]

100 watt light bulb converts 100 Joules of electrical energy into light and waste heat every second

If the power of an electric heater is 1 kW, and it runs for an hour, we say that it has consumed one kilowatt-hour (kWh) of energy. As 1 kilowatt is 1000 watts, from the definition of the watt this is 1000 joules per second. There are 3600 seconds in an hour, so:

1 kWh = 3600 × 1000 = 3.6 × 10^6 joules (3.6 MJ).

Renewable Energy Technology

Definitions

Common Energy and Power Units

- Joule is a small unit of energy and larger multiples are often used.

  kJ (10^3) MJ (10^6) GJ (10^9) TJ (10^{12})

❖ **Watt-hour [Wh]:**

The energy equivalent of 1W developed or consumed in one hour.

❖ **Kilowatt-hour [kWh]:**

The energy equivalent of 1kW developed or consumed in one hour (3600 seconds).

$$1\ [kWh] = 100\ [W] \times 1\ [h]$$
$$= 1000\ [J/s] \times 3600\ [s]$$
$$= 3.6 \times 10^6\ [J]$$
$$= 3600\ [kJ]$$
$$= 3.6\ [MJ]$$

❖ **Power use of kW, MW, GW and TW**

$$1\ [kW] = 1000\ W$$
$$= 1000\ J/s$$
$$= 1\ kJ/s$$

❖ **British Thermal Units (BTU):**

1 [BTU] = 1055 [J] = 1.055 [kJ]

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Energy from a Coffee & Snickers Bar:

- **Coffee = 60 Kilocalories**
- **Snickers Bar = 280 Kilocalories**
- **Total = 340 Kilocalories (1 Kcal = 4.2 kJ)**

  = 1428 kJ

Power Consumption of a student in classroom (assuming sitting still concentrating on lecture)

= 120 W (1W= 1 J/s)

= 120 J/s

During a 1 hour lecture you consume (120 X 3600) Joules

= 432000 J

= 432 kJ

How long should a lecture be to use the energy from a coffee & a Snickers Bar

1428/432 = 3.3

3 hours and 18 mins

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Definitions

What is Renewable Energy?

Renewable energy is the term used to cover those energy flows that occur naturally and repeatedly in the environment and can be harnessed for human benefit.

or

Renewable energy is the energy derived from natural processes that do not involve the consumption of exhaustible resources such as fossil fuels and uranium.

or

Energy obtained from continuous or repetitive currents of energy recurring in the natural environment.

or

Energy flows which are replenished at the same rate as they are used.

or

Energy from a source that is not depleted when used.

The ultimate sources of most of this energy are the sun, gravity and the earth's rotation.

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Definitions

Non Renewable Energy:

Non renewable energy **is the energy obtained from *static stores of energy* that remain bound unless released by human interaction.**

Examples: **Nuclear fuels and fossil fuels (coal, oil, natural gas).**

- **The energy is initially an isolated energy potential and external action is required to initiate the supply of energy for practical purposes.**
- **Non renewable energy supplies are also called *finite supplies*.**

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Why Renewable Energy?

- Non renewable resources are limited
- Renewable energy has supply security
- Ensures sustainability
  - Energy
  - Environment
  - Society
  - Economy

Sustainability

Definition: "Meeting *the needs of the present generation without compromising the ability of future generations to meet their needs."* Brundtland-1987

Ideally, a sustainable energy source is one that:

■ is not substantially depleted by continued use

■ does not entail significant pollutant emissions or other environmental problems

■ does not involve the perpetuation of substantial health hazards or social injustices.

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Advantages of Renewable Energy

- Abundant availability of renewable energy resources.
- No fuel cost (except for operation and maintenance).
- Lower overall environmental impact as compared to conventional fossil and nuclear fuels.
- Considerably lower emission of greenhouse gases.
- Short implementation time compare to conventional power plant.
- Reliability of electricity supply in decentralized applications.
- Suitable for off-grid remote applications.
- Possibility to get rid of a portion of the generated house hold waste materials.
- Hydroelectric dams can be used for regulating waterways, flood-control.

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Drawbacks of Renewable Energy Sources

- Many renewable energy sources are intermittent (hourly, diurnal, seasonal, annual variations)
- Supplies are often diffuse and need to be concentrated (or processed -e.g. biomass)
- Necessity of back-up power due to intermittency
- Need for energy storage (difficult for wind, solar PV, easier for hydro and biomass)
- Renewable energy can make large tracts of land unusable for competing uses
- Disrupt marine life, bird life and flora/fauna produce visual and noise pollution.
- Currently longer system payback times, more expensive energy price

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Main Renewable Energy Sources

- Solar Energy
- Wind Energy
- Biomass
- Geothermal Energy
- Tidal Energy
- Wave Energy
- Fuel Cell
- Others (Ocean, thermal energy conversion, MHD generator etc.)

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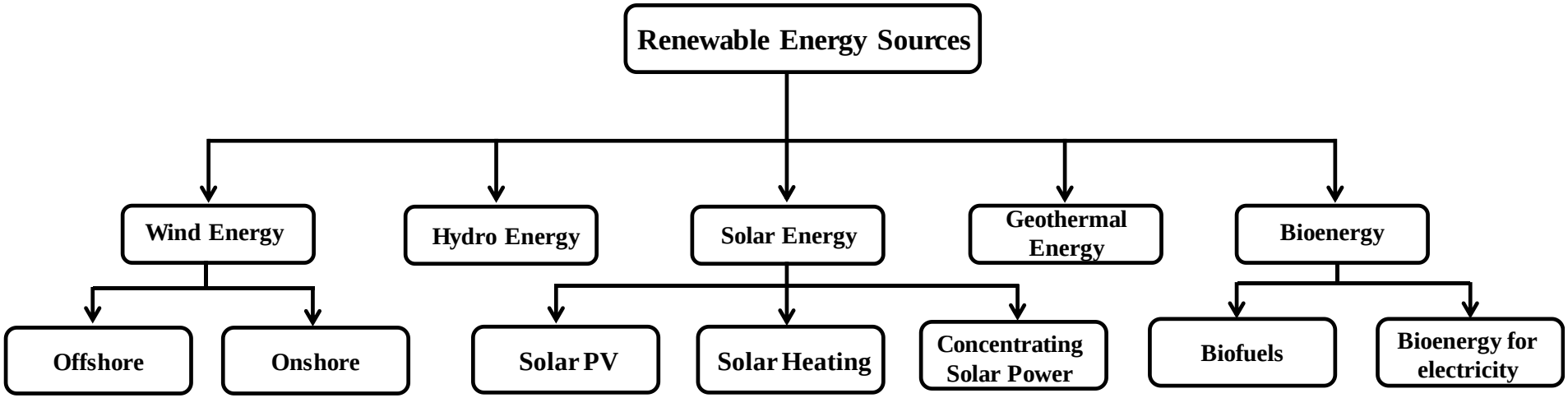

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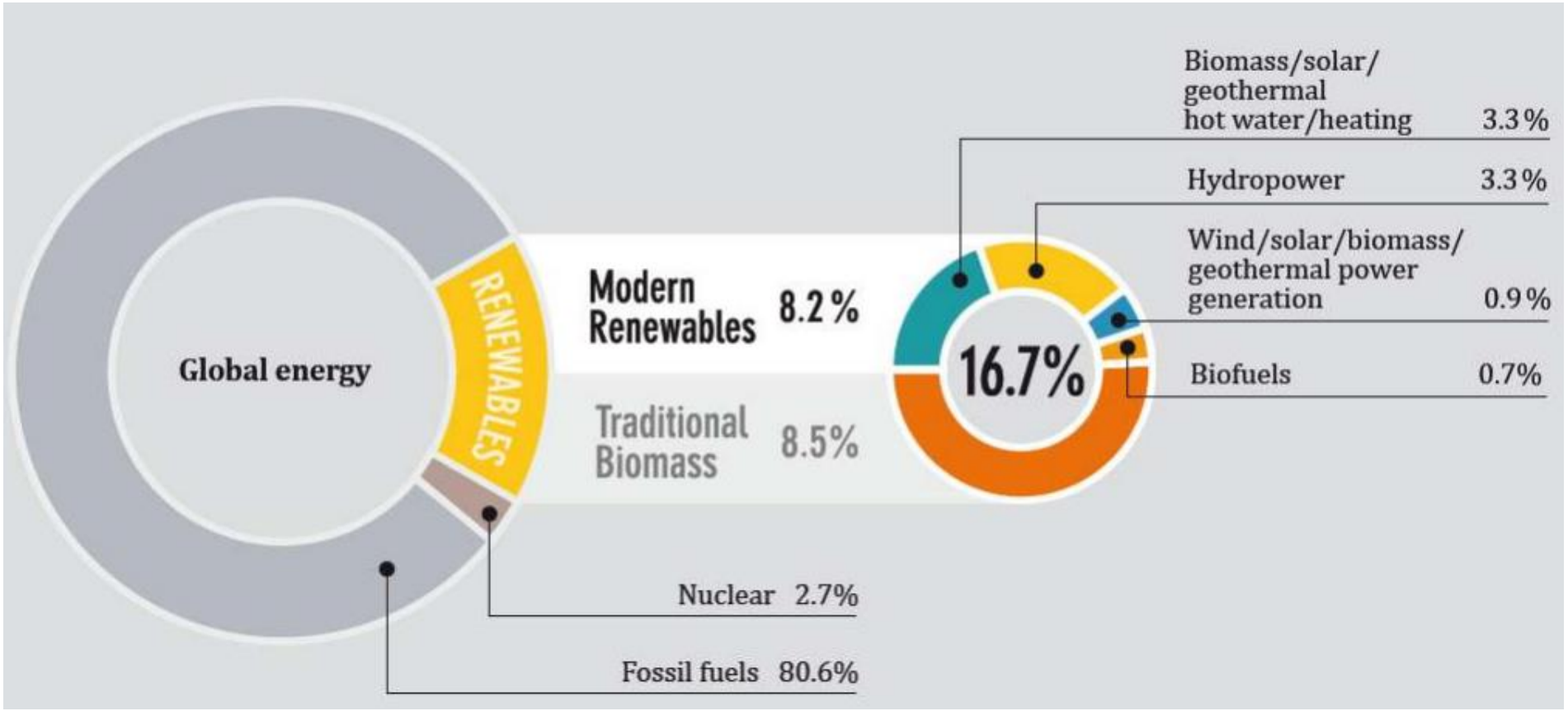
Renewable Energy Share of Global Final Energy Consumption, 2010



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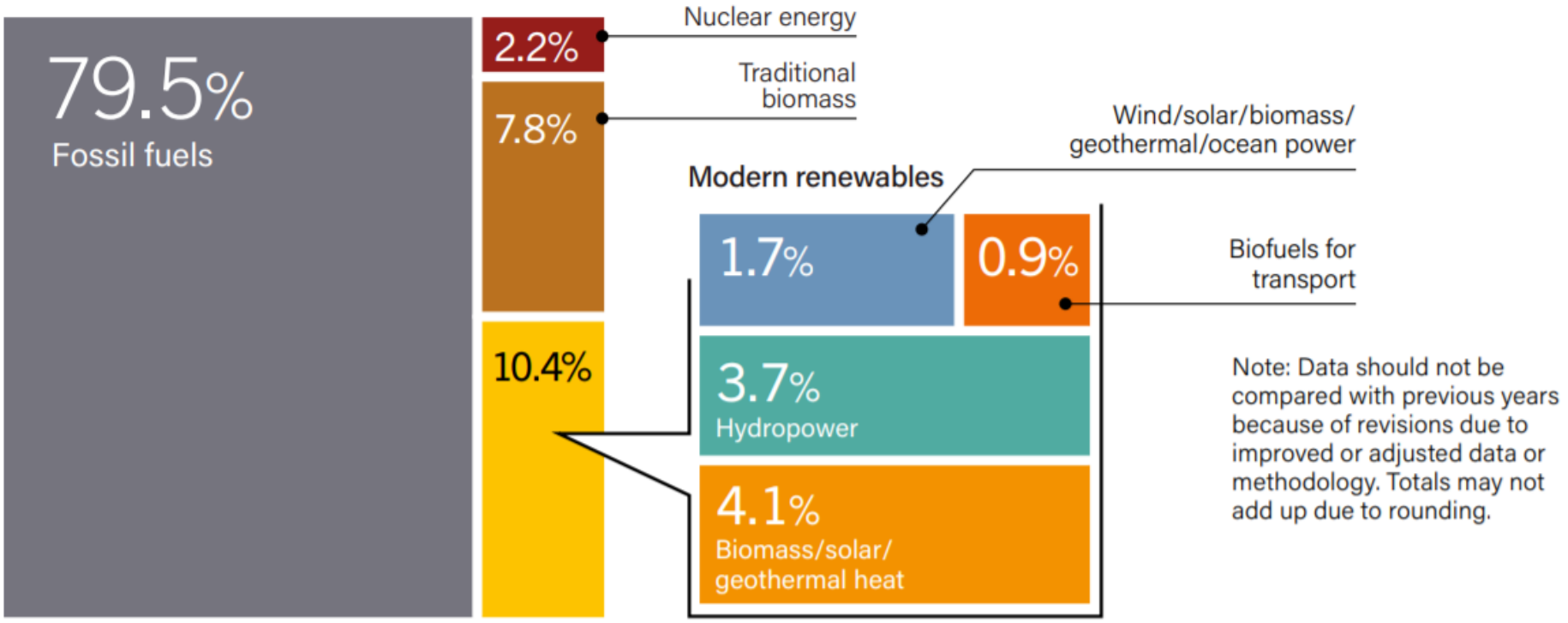
Renewable Share of Total Final Energy Consumption, 2016



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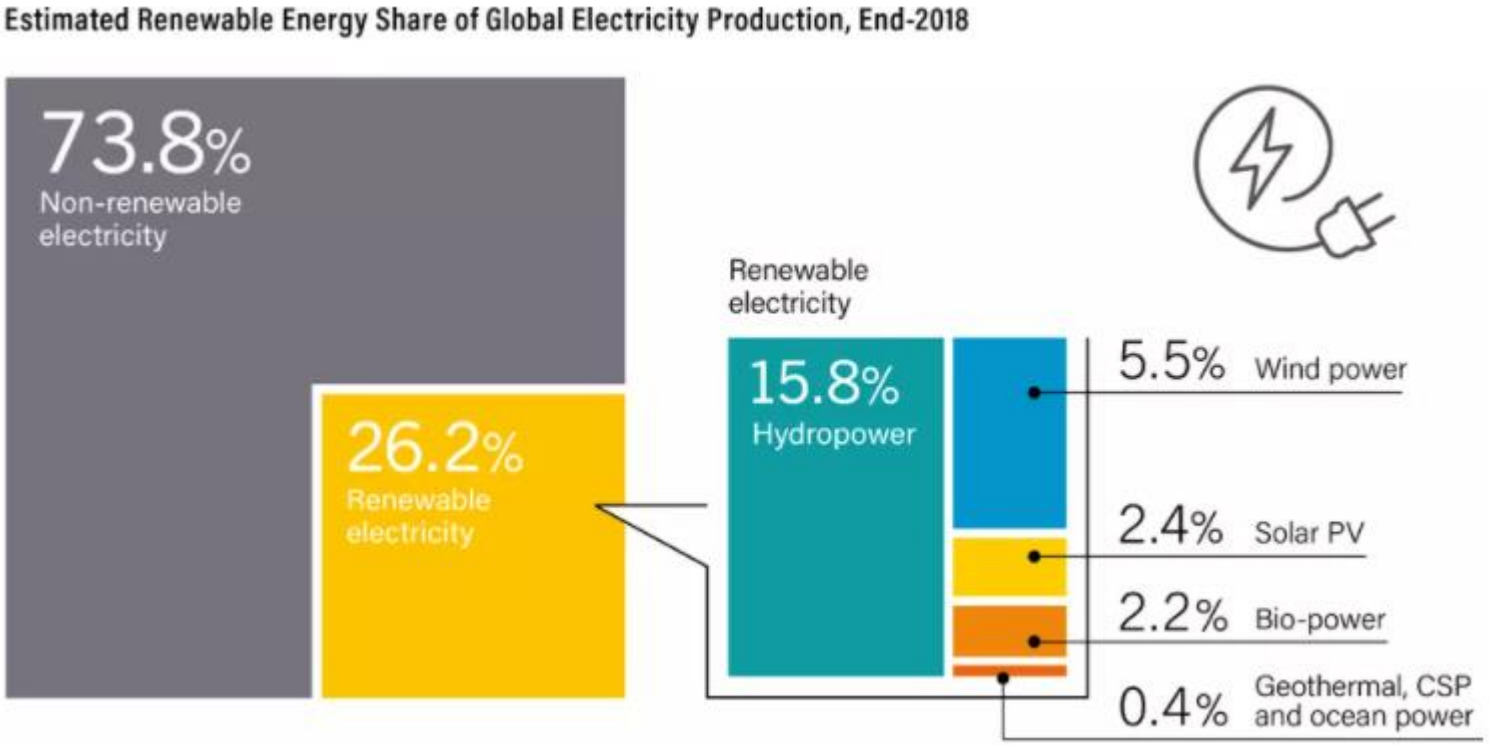
Renewable Share of Total Final Energy Production, 2018



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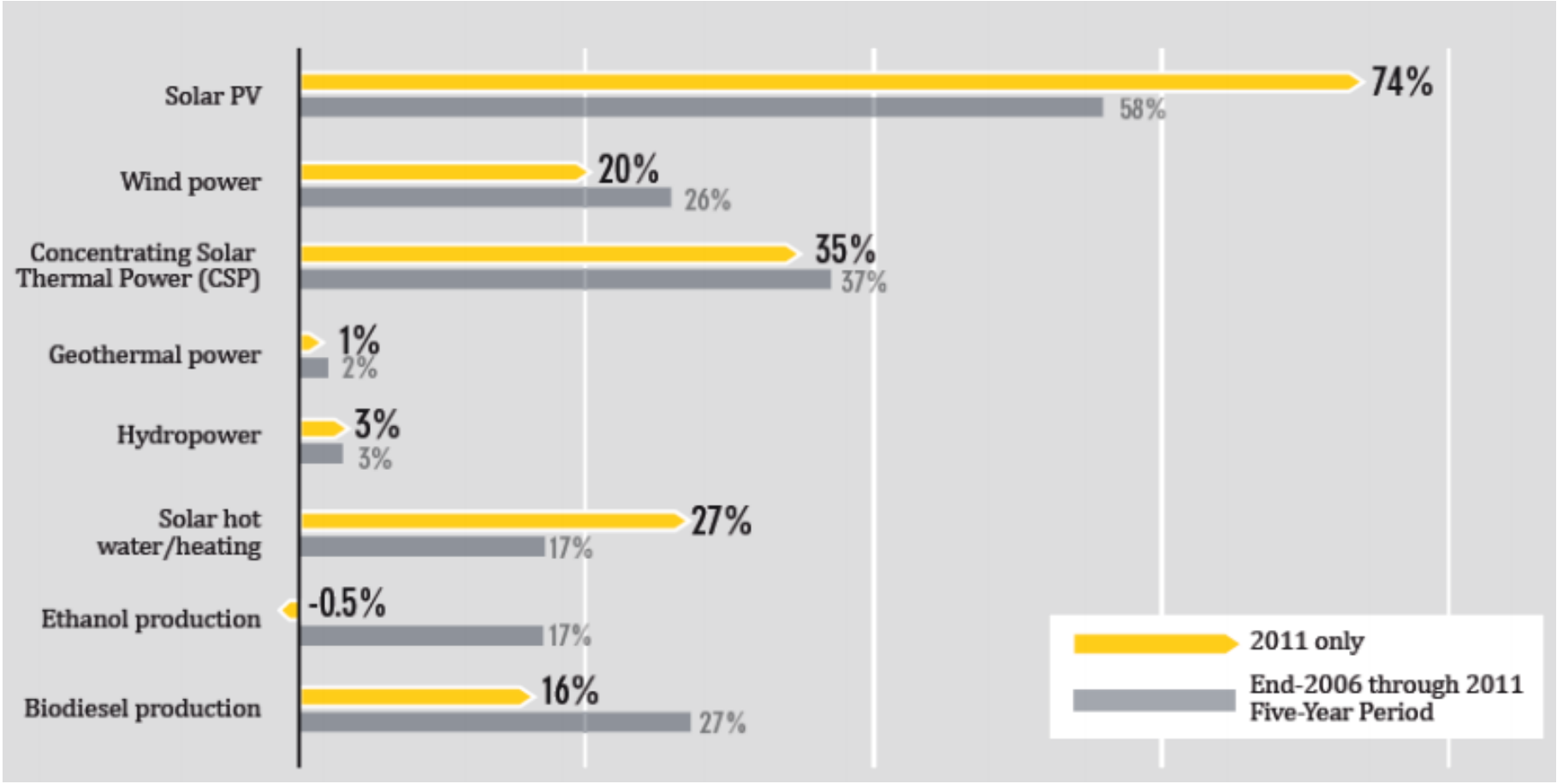
Average Annual Growth Rates of Renewable Energy Capacity and Biofuels Production, 2006-2011



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Global Renewable Power Capacity, 2007-2017

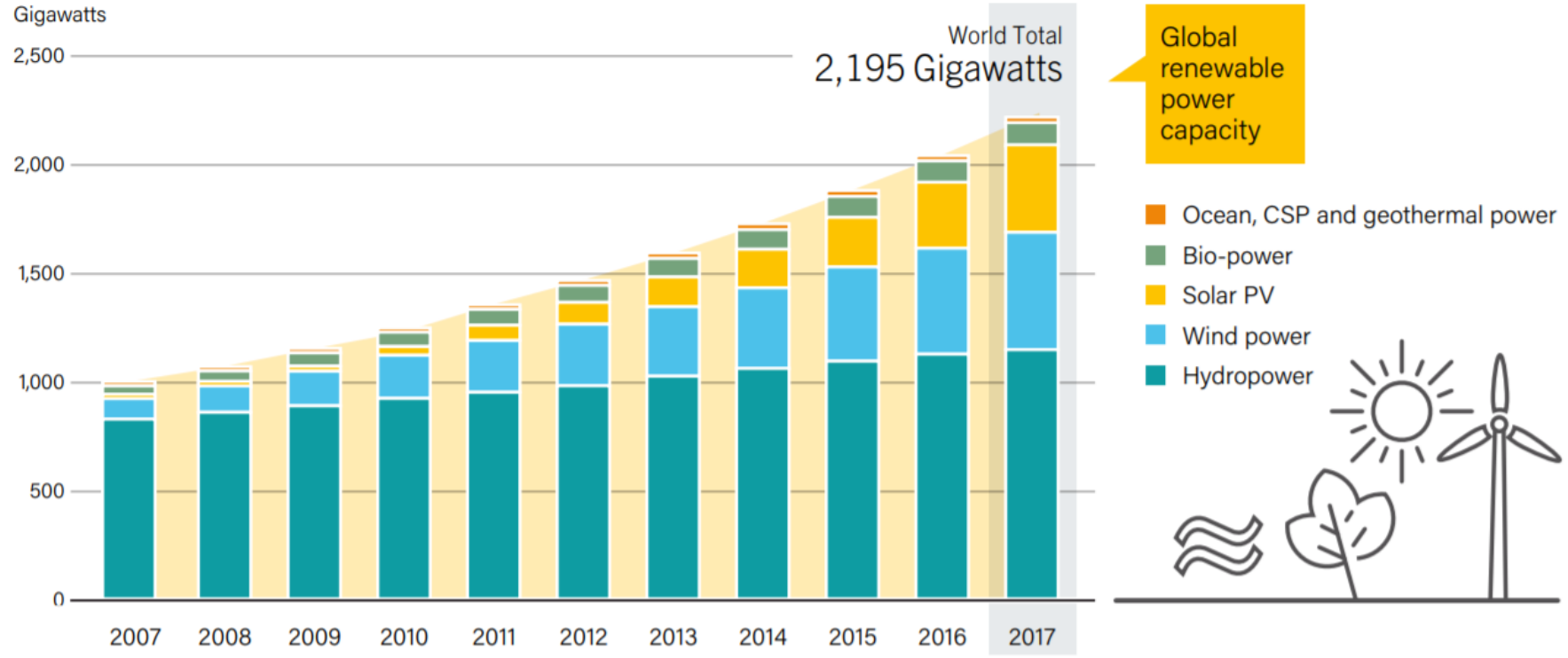

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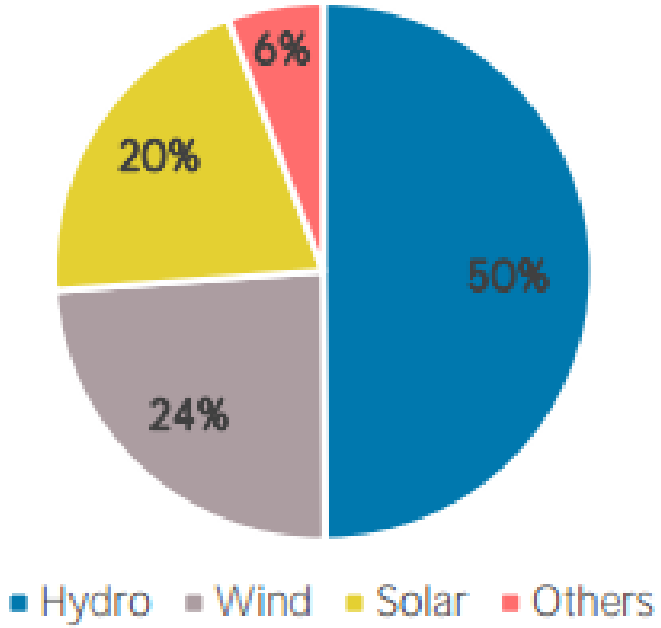
Table 1: Total installed capacity of RESs in 2016-2017 .

	2016	2017
Renewable power capacity (including hydro)	2,017 GW	2,195 GW
Renewable power capacity (not including hydro)	922 GW	1,081 GW
Hydropower capacity	1,095 GW	1,114 GW
Bio-power capacity	114 GW	122 GW
Bio-power generation (annual)	501 TWh	555 TWh
Geothermal power capacity	12.1 GW	12.8 GW
Solar PV capacity	303 GW	402 GW
Concentrating solar thermal power (CSP) capacity	4.8 GW	4.9 GW
Wind power capacity	487 GW	539 GW
Ocean energy capacity	0.5 GW	0.5 GW

Worldwide Renewable Capacity Statistics

Renewable generation capacity by energy source

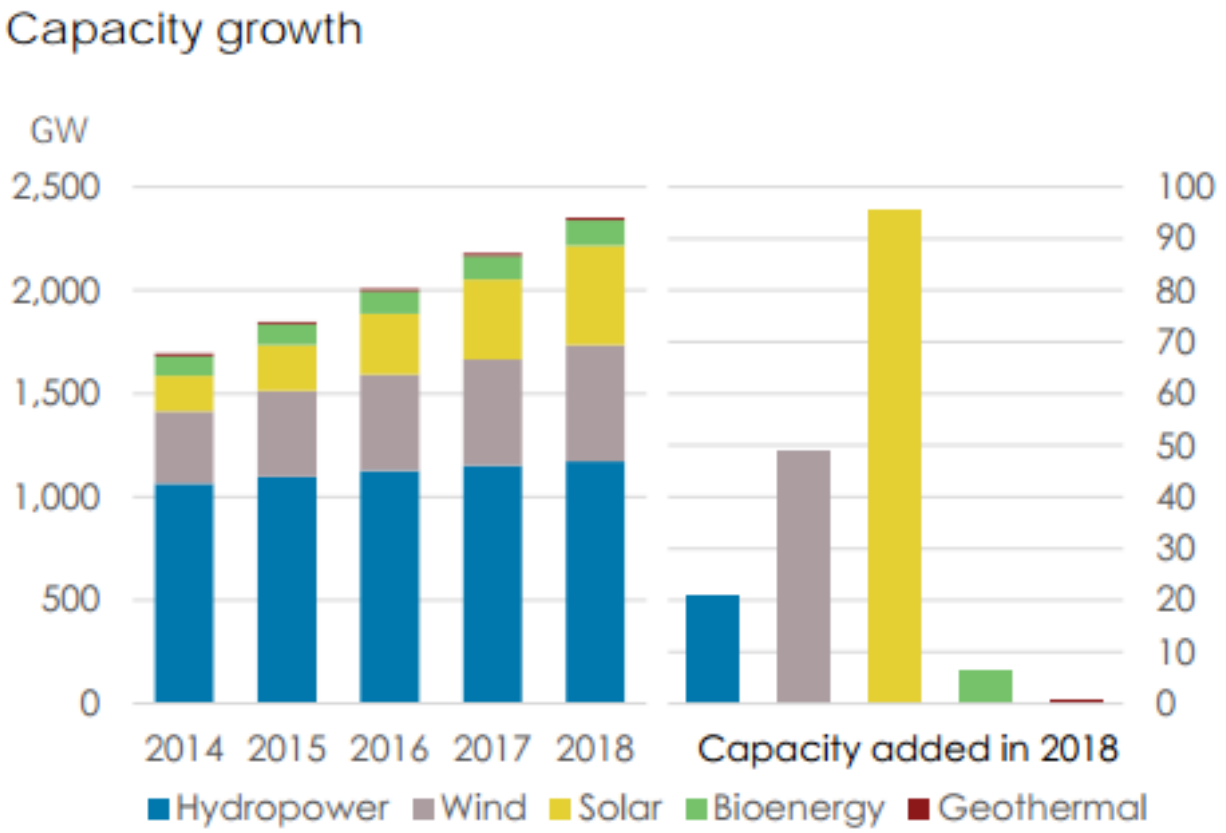


At the end of 2018, global renewable generation capacity amounted to 2 351 GW. Hydro accounted for the largest share of the global total, with an installed capacity of 1 172 GW.*

Wind and solar energy accounted for most of the remainder, with capacities of 564 GW and 486 GW respectively. Other renewables included 115 GW of bioenergy, 13 GW of geothermal energy and 500 MW of marine energy (tide, wave and ocean energy).

Source: https://www.irena.org/

Worldwide Renewable Capacity Statistics



Source: https://www.irena.org/

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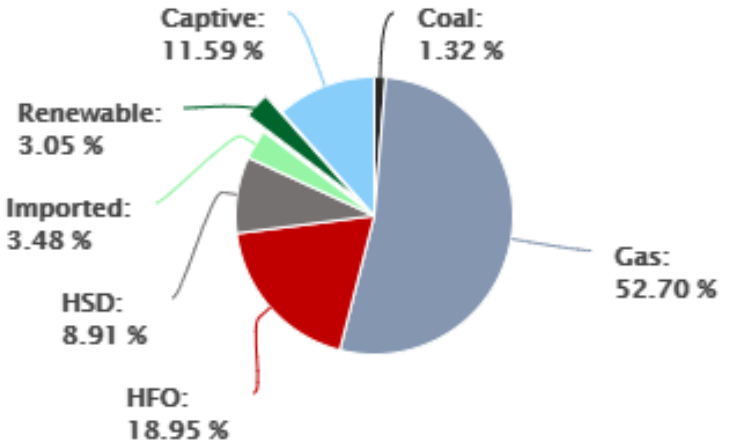
Current Power generation scenario of Bangladesh

(Source: http://www.sreda.gov.bd/**)**

Technology	Off-Grid	On-Grid	Total
Solar	291.55	52.92	344.48
Wind	2	1.18	3.18
Hydro	-	230	230
Biogas to Electricity	0.68	-	0.68
Biomass to Electricity	0.40	-	0.40
Total	294.63	284.11	578.74



Total Power Generation Capacity = 18,976.74 MW

(Including Off-Grid RE)

Renewable Energy Share = 3.05%

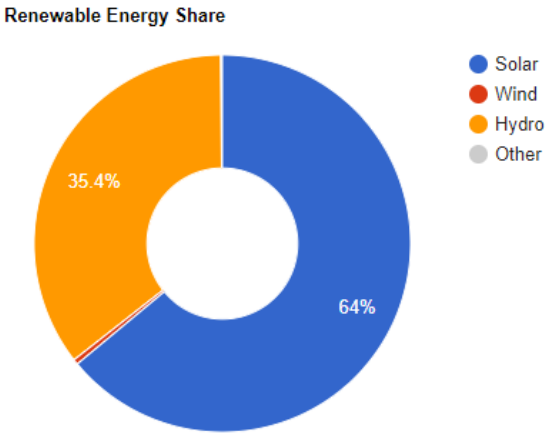
Renewable Energy Technology

Current Power generation scenario of Bangladesh

(Source: http://www.sreda.gov.bd/**)**

Renewable Energy Installed Capacity: **649.46 MW**

Techlology	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	327.48	88.06	415.53
Wind	2	0.9	2.9
Hydro	0	230	230
Biogas to Electricity	0.63	0	0.63
Biomass to Electricity	0.4	0	0.4
Total	**330.51**	**318.96**	**649.46**



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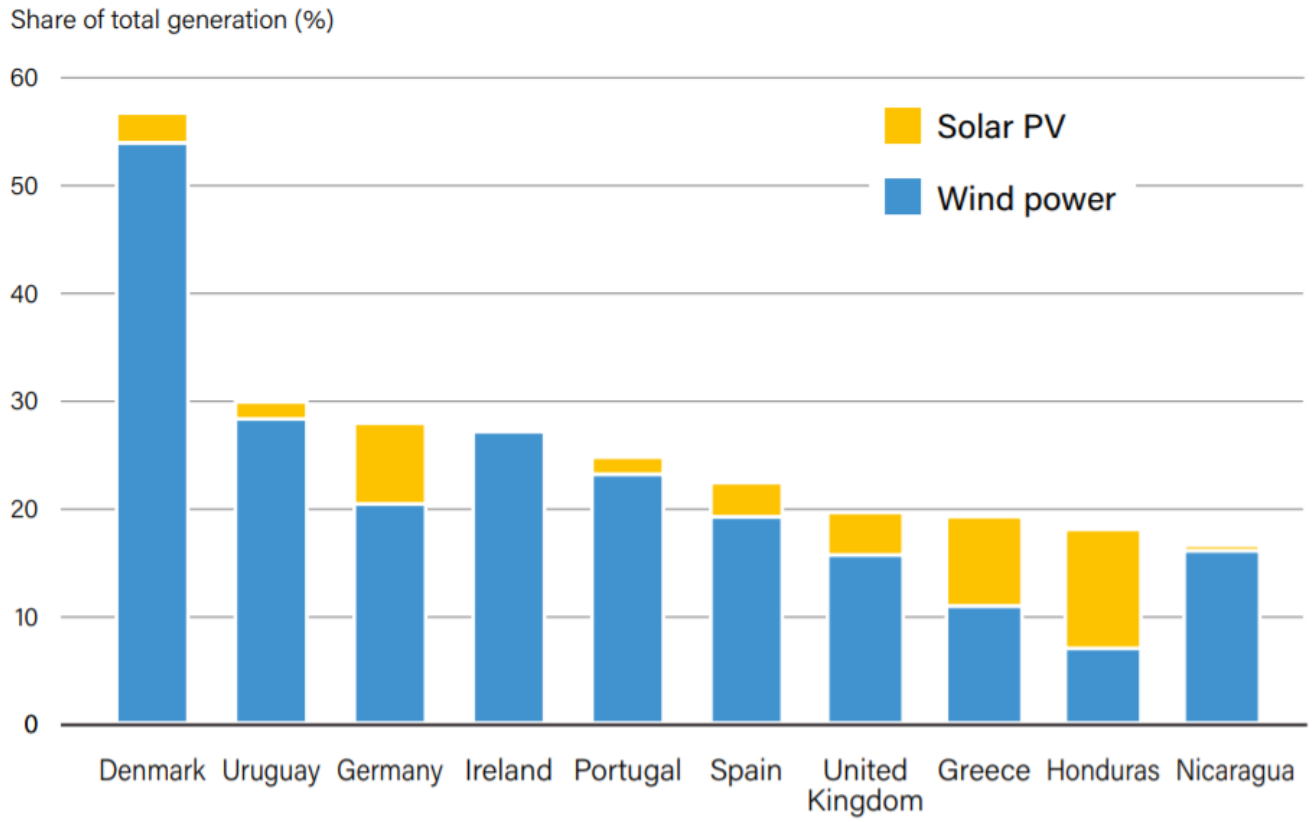
Share of Electricity Generation from Variable Renewable Energy, Top 10 Countries, 2017



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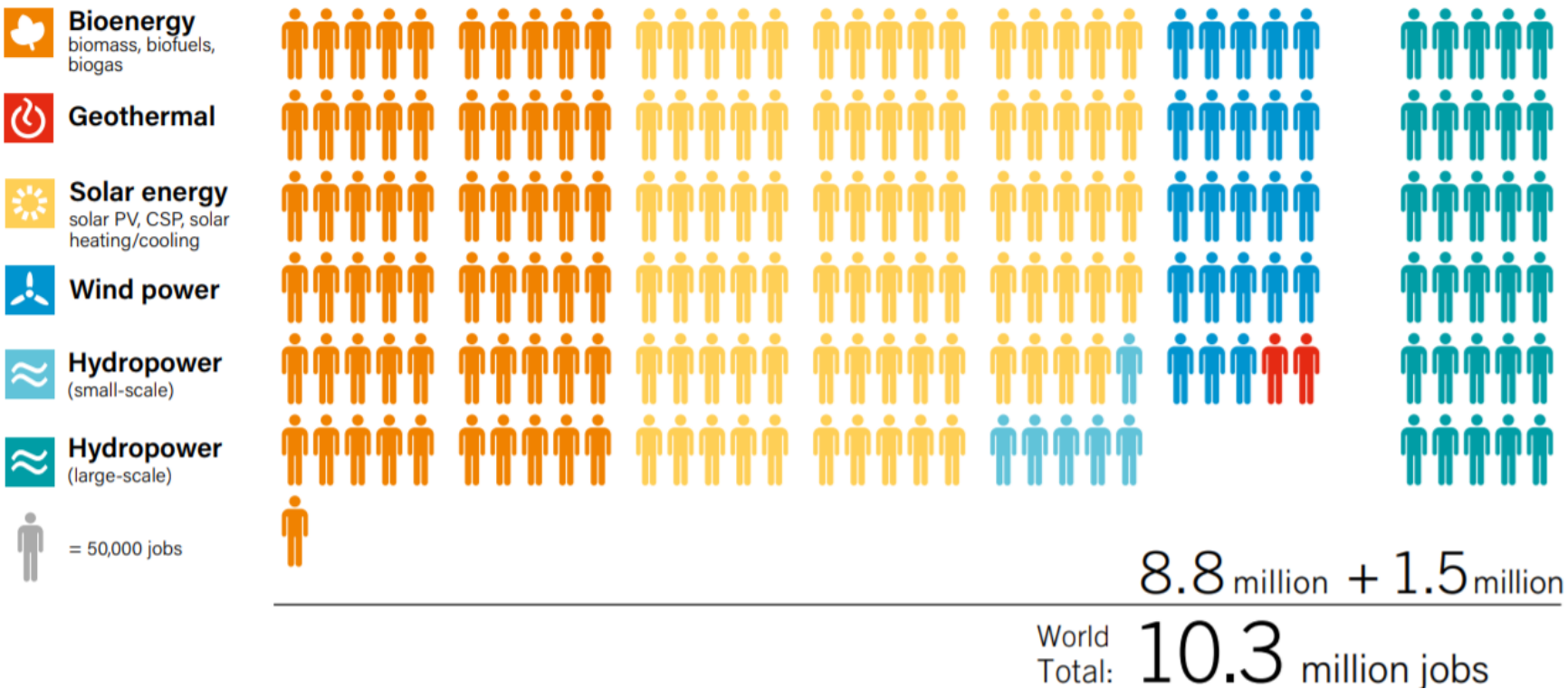
The renewable energy sector employed, directly and indirectly, approximately 10.3 million people in 2017

Jobs in Renewable Energy



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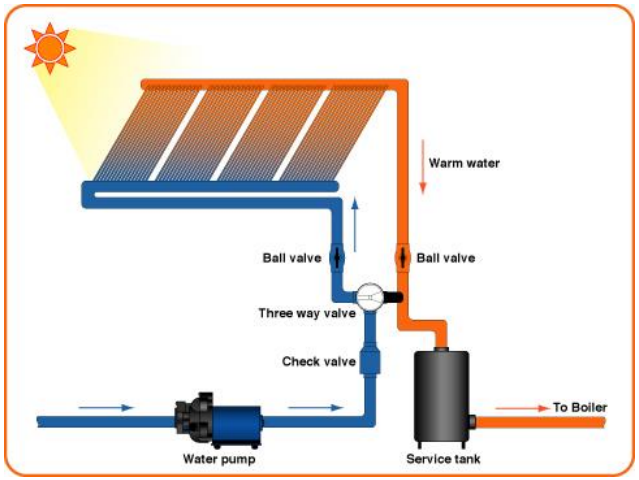
Solar Energy:

The amount of solar energy incident on the earth every year is:

- **Equivalent to 160 times the energy stored in the world's proven reserves of fossil fuels.**
- **Equivalent to more than 15,000 times the world's annual use of fossil and nuclear fuels and hydropower.**

Solar Thermal:

- **Complex collectors to gather solar radiation to produce temperatures high enough to drive steam turbines to produce electric power.**
  - **For example, a turbine fed from parabolic trough collectors might take steam at 750 K and eject heat into atmosphere at 300 K will have a ideal thermal (Carnot) efficiency of about 60%. Realistic overall conversion (system) efficiency of about 35% is feasible.**



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Solar Photovoltaics:

- **The direct conversion of sun's rays to electricity.**
- **The efficiency (the ratio of the maximum power output and the incident radiation flux) of the best single-junction silicon solar cells has now reached to 24% in laboratory test conditions.**
  - **The best silicon commercially available PV modules have an efficiency of about 20%.**
  - **More common module efficiency is between 14-15% at standard conditions.**

Irradiance & Irradiation:

- **Irradiance is given in W/m^2 and is represented by the symbol G. *The rate at which radiant energy is incident on a surface per unit area of surface*.**
- **Irradiation is given in J/m^2 and is the incident energy per unit area on a surface - determined by integration of irradiance over a specified time, usually an hour or a day.**
- ***Insolation is a term used to refer solar energy irradiation.***
- **Radiosity is the rate at which radiant energy leaves a surface, per unit area, by combined emission, reflection and transmission.**

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