Green and Sustainable Technologies

Lesson 3: Renewable Energy

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What we have discussed so far?

- Introduction to sustainability
- Sustainable Development Goals: A Brief Introduction
- The Blue-Green Economic Policy: The Creator of New Prospects in the Economy
- What is green technology?
- Importance of green technology
- Evolution of green technology
- Emerging green technologies
- Why is Green Technology Necessary?
- Principles of Green Engineering and principles of green chemistry

Today’s Outline

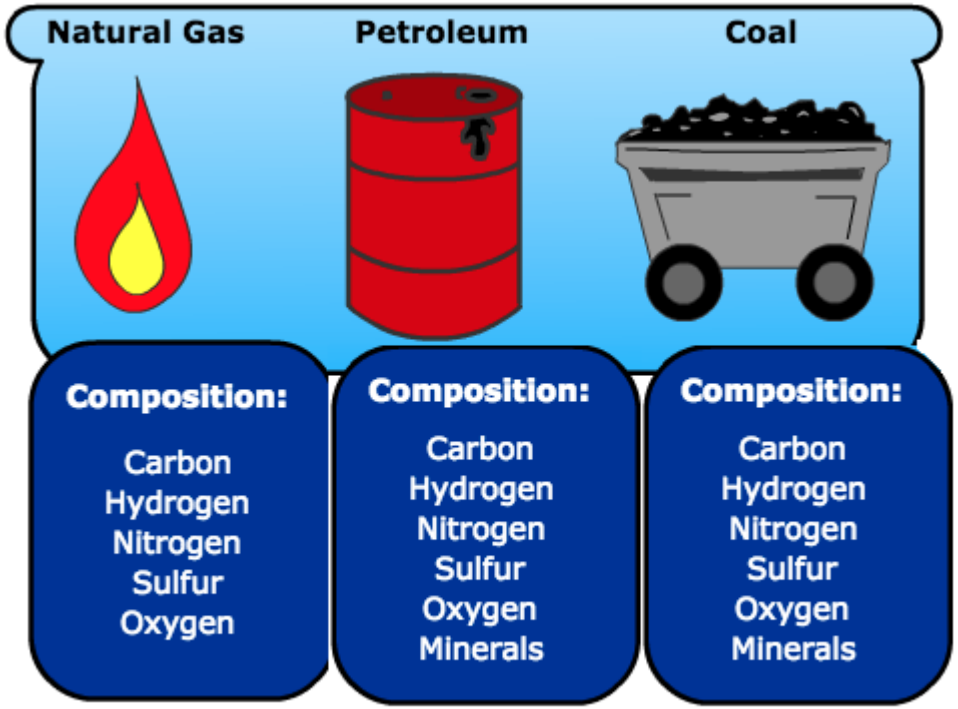
Introduction to renewable energy

Introduction

Nonrenewable energy

- Energy obtained from static stores of energy that remain bound unless released by human interaction.
- Examples are fossil fuels of coal, oil and natural gas and nuclear fuels.
- This type of energy is also called finite energy or conventional sources of energy.

- Fossil energy is contained in
  - coal,
  - oil and
  - natural gas.



https://www.e-education.psu.edu/egee102/node/1950

Environmental and Social problems of fossil fuels

(a) Water pollution.

(b) Hazardous air pollutants

(c) Ambient air quality.

(d) Marine pollution

(e) Solid waste disposal

(f) Land use and siting impact.

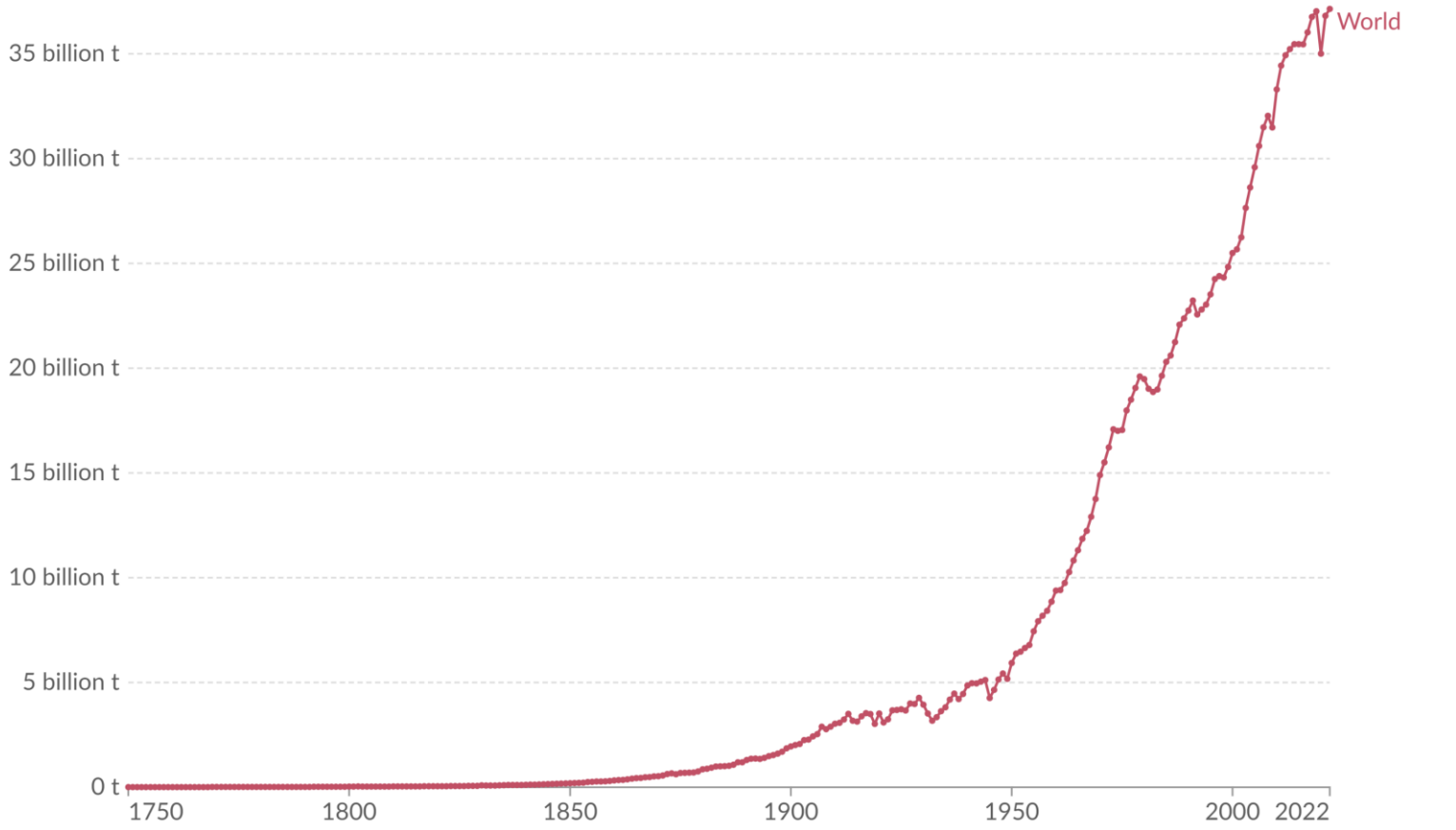
(g) Acid rain

(h) Stratospheric ozone depletion

(i) Global climate change(greenhouse effect)

Annual CO_2 emissions

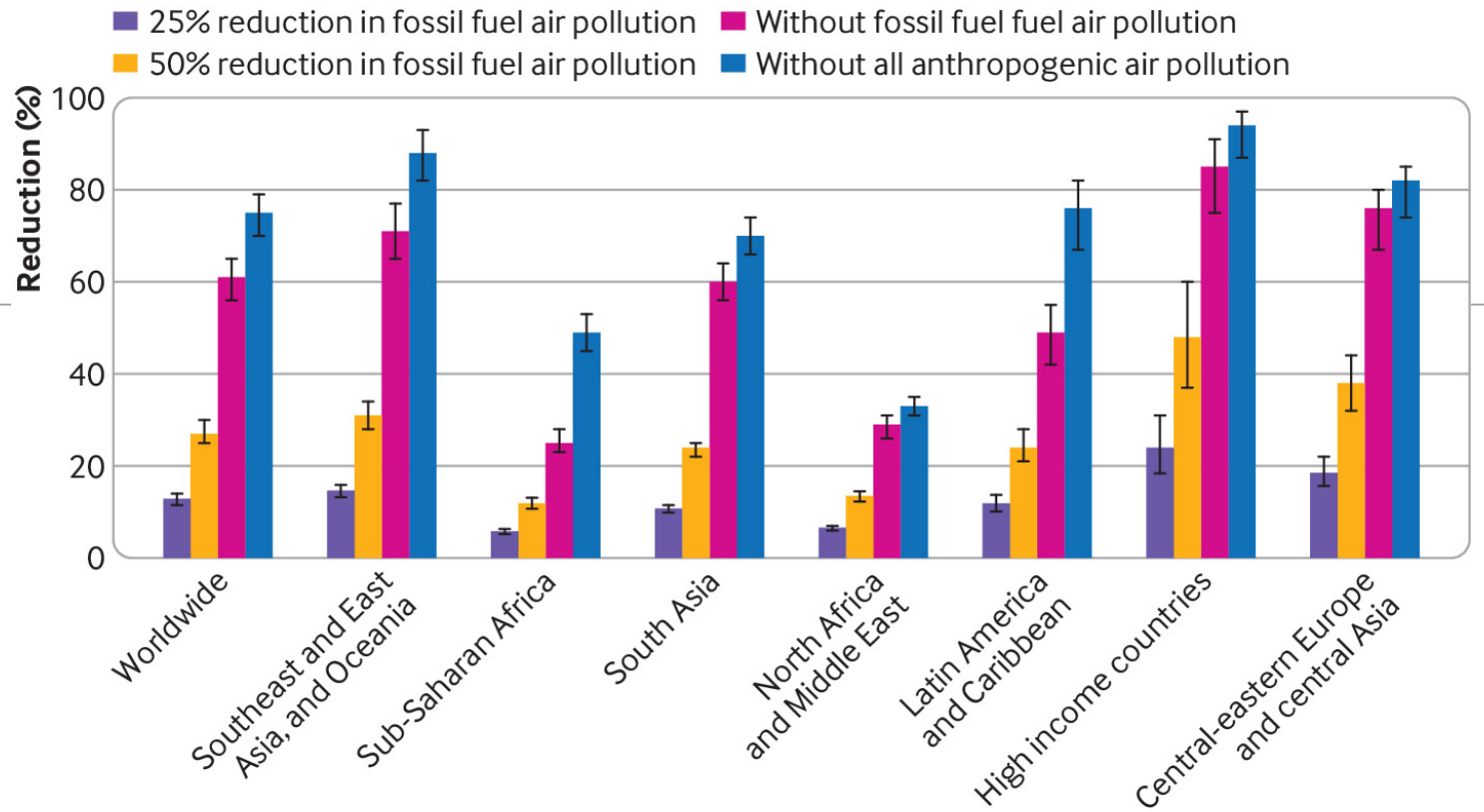
Carbon dioxide (CO_2) emissions from fossil fuels and industry[1]. Land-use change is not included.



Data source: Global Carbon Budget (2023)

OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

1. Fossil emissions: Fossil emissions measure the quantity of carbon dioxide (CO_2) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO_2 includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.



Percentage reductions in annual deaths attributable to air pollution from removing fossil fuel related and all anthropogenic emissions of $PM_{2.5}$ and O_3 for seven macro-regions and the world. The yellow bars depict the "half way" scenario by assuming that 50% of the fossil fuel phase-out is achieved and the purple bars indicate the "quarter way" scenario by assuming that 25% is achieved. The error bars indicate the 95% CI

Lelieveld J, Haines A, Burnett R, Tonne C, KlingmÃ¼ller K, MÃ¼nzel T et al. Air pollution deaths attributable to fossil fuels: observational and modelling study *BMJ* 2023; 383 :e077784 doi:10.1136/bmj-2023-077784

Renewable energy

- Energy obtained from regenerative or virtually in exhaustible sources of energy occurring in the natural environment like solar energy, wind energy etc.
- This is also referred as non-conventional sources of energy.
- Renewable energy is a crucial source for sustainable economic growth, particularly in developing countries and less developed economies to attract foreign investment.

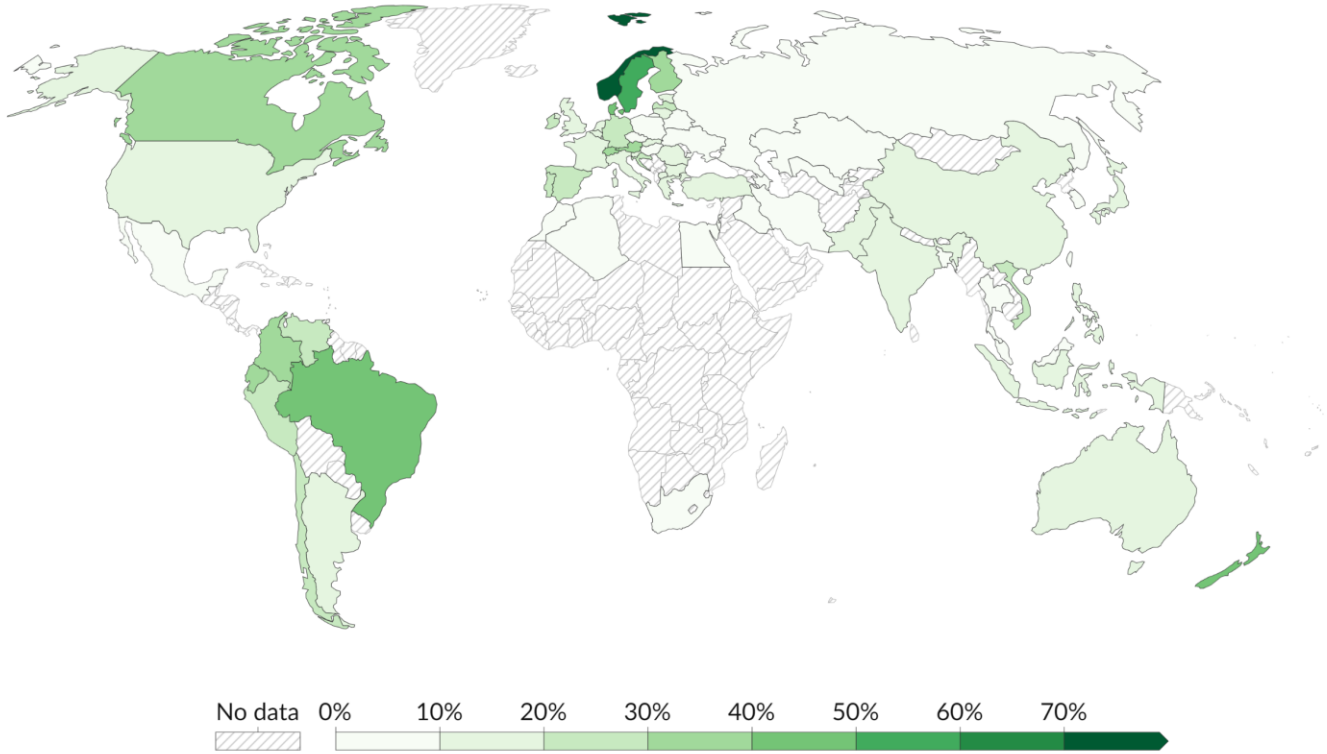
Renewable energy sources and their use

Energy sources	Energy conversion and usage options
Hydropower	Power generation
Morden biomass	Heat and power generation, pyrolysis, gasification, digestion
Geothermal	Urban heating, power generation, hydrothermal, hot dry rock
Solar	Solar home systems, solar dryers, solar cookers
Direct solar	Photovoltaic, thermal power generation, water heaters
Wind	Power generation, wind generators, windmills, water pump
Wave and tide	Numerous design, barrage, tidal stream

Share of primary energy consumption from renewable sources, 2022

Our World in Data

Measured as a percentage of primary energy[1] using the substitution method[2]. Renewables include hydropower, solar, wind, geothermal, bioenergy, wave, and tidal, but not traditional biofuels, which can be a key energy source, especially in lower-income settings.



Data source: Energy Institute - Statistical Review of World Energy (2023)

OurWorldInData.org/energy | CC BY

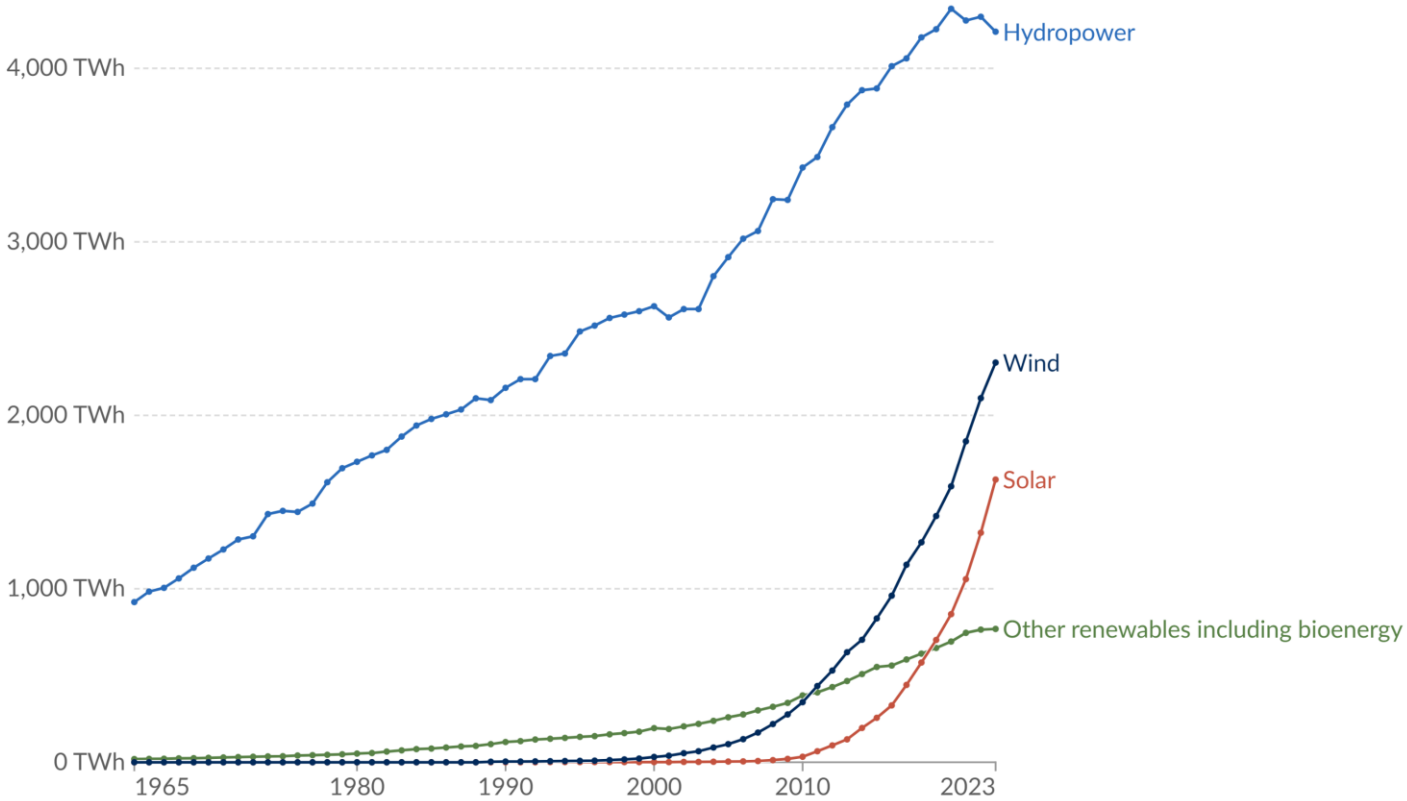
1. Primary energy: Primary energy is the energy available as resources – such as the fuels burnt in power plants – before it has been transformed. This relates to the coal before it has been burned, the uranium, or the barrels of oil. Primary energy includes energy that the end user needs, in the form of electricity, transport and heating, plus inefficiencies and energy that is lost when raw resources are transformed into a usable form. You can read more on the different ways of measuring energy in our article.

2. Substitution method: The 'substitution method' is used by researchers to correct primary energy consumption for efficiency losses experienced by fossil fuels. It tries to adjust non-fossil energy sources to the inputs that would be needed if it was generated from fossil fuels. It assumes that wind and solar electricity is as inefficient as coal or gas. To do this, energy generation from non-fossil sources are divided by a standard 'thermal efficiency factor' – typically around 0.4 Nuclear power is also adjusted despite it also experiencing thermal losses in a power plant. Since it's reported in terms of electricity output, we need to do this adjustment to calculate its equivalent input value. You can read more about this adjustment in our article.

Modern renewable energy generation by source, World

Our World in Data

Measured in terawatt-hours[1].



Data source: Ember (2024); Energy Institute - Statistical Review of World Energy (2023)
OurWorldInData.org/renewable-energy | CC BY

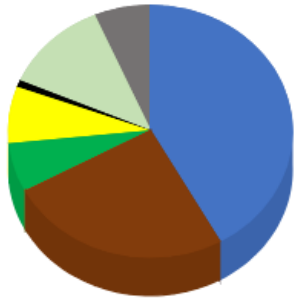
1. Watt-hour: A watt-hour is the energy delivered by one watt of power for one hour. Since one watt is equivalent to one joule per second, a watt-hour is equivalent to 3600 joules of energy. Metric prefixes are used for multiples of the unit, usually: - kilowatt-hours (kWh), or a thousand watt-hours. - Megawatt-hours (MWh), or a million watt-hours. - Gigawatt-hours (GWh), or a billion watt-hours. - Terawatt-hours (TWh), or a trillion watt-hours.

https://ourworldindata.org/renewable-energy

DAILY NET ELECTRICITY GENERATION

Date: Sunday, May 26, 2024

Total Net Energy	37.36 GWh	Peak Demand	2020.4 MW
• Renewable	27.95 GWh (74.81%)	• Renewable	1481.1 MW (73.3%)
• Fossil Fuel	9.41 GWh (25.19%)	• Fossil Fuel	539.3 MW (26.7%)



CEB Hydro	15.66 GWh
CEB Thermal Coal	9.39 GWh
CEB Thermal Oil	0.02 GWh
CEB Wind	2.34 GWh
SPP Solar [1]	2.71 GWh
SPP Biomass [2]	0.33 GWh
SPP Minihydro	4.49 GWh
SPP Wind	2.42 GWh
IPP Thermal Oil	0 GWh

Total Net Energy	37.36 GWh
Auxiliary Consumption	1.28 GWh
Total Gross Energy	38.64 GWh

Note:

1. Telemetered values of 10MW Solar Parks, estimated values of Bulk 01-10 MW Solar plants and Rooftop Solar plants were included.
2. Telemetered values of 102 Nos. of Mini Hydro Plants and estimated values of remaining Mini Hydro Plants were included.

* IPP: independent power producers; SPP: small power producers
* Information not available in daily records will be included in annual publications.

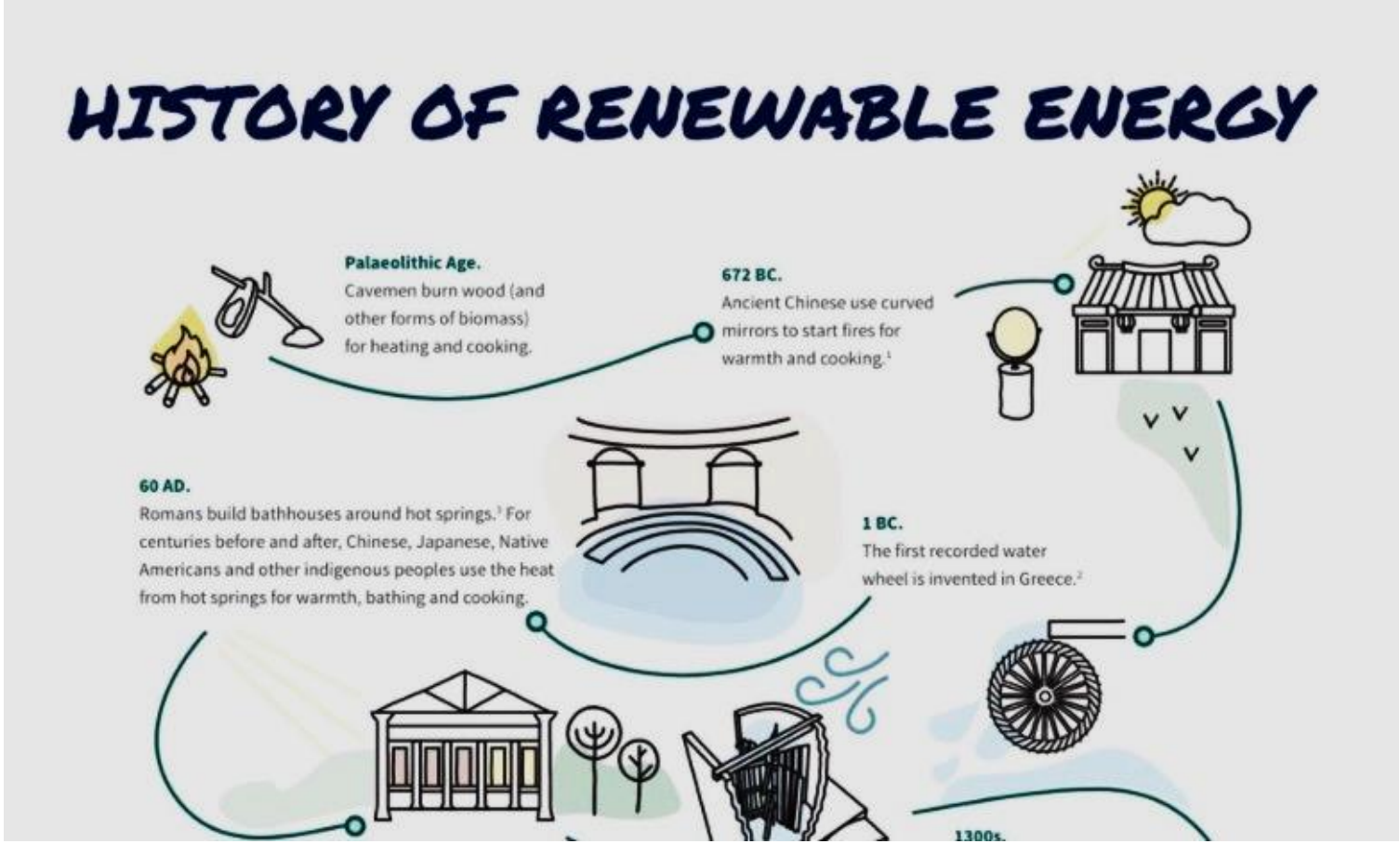
https://www.ceb.lk/

The term of **Renewable energy** refers to primary energies that are regarded as inexhaustible in terms of human (time) dimensions.

Characteristics:

- They are continuously generated by the energy sources solar energy, geothermal energy and tidal energy.
- The energy produced within the sun is responsible for a multitude of other renewable energies (such as wind and hydropower) as well as renewable energy carriers (such as solid or liquid biofuels).
- The energy content of the waste can only be referred to as renewable if it is of non-fossil origin (e.g. organic domestic waste, waste from the food processing industry).
- Properly speaking, only naturally available primary energies or primary energy carriers are renewable but not the resulting secondary or final energies or the related energy carriers.

- Utilization of renewable energies is not at all new!!!
- (in the history of mankind renewable energies have for a long time been the primary possibility of generating energy)



https://www.infographicsarchive.com/history-of-renewable-energy/

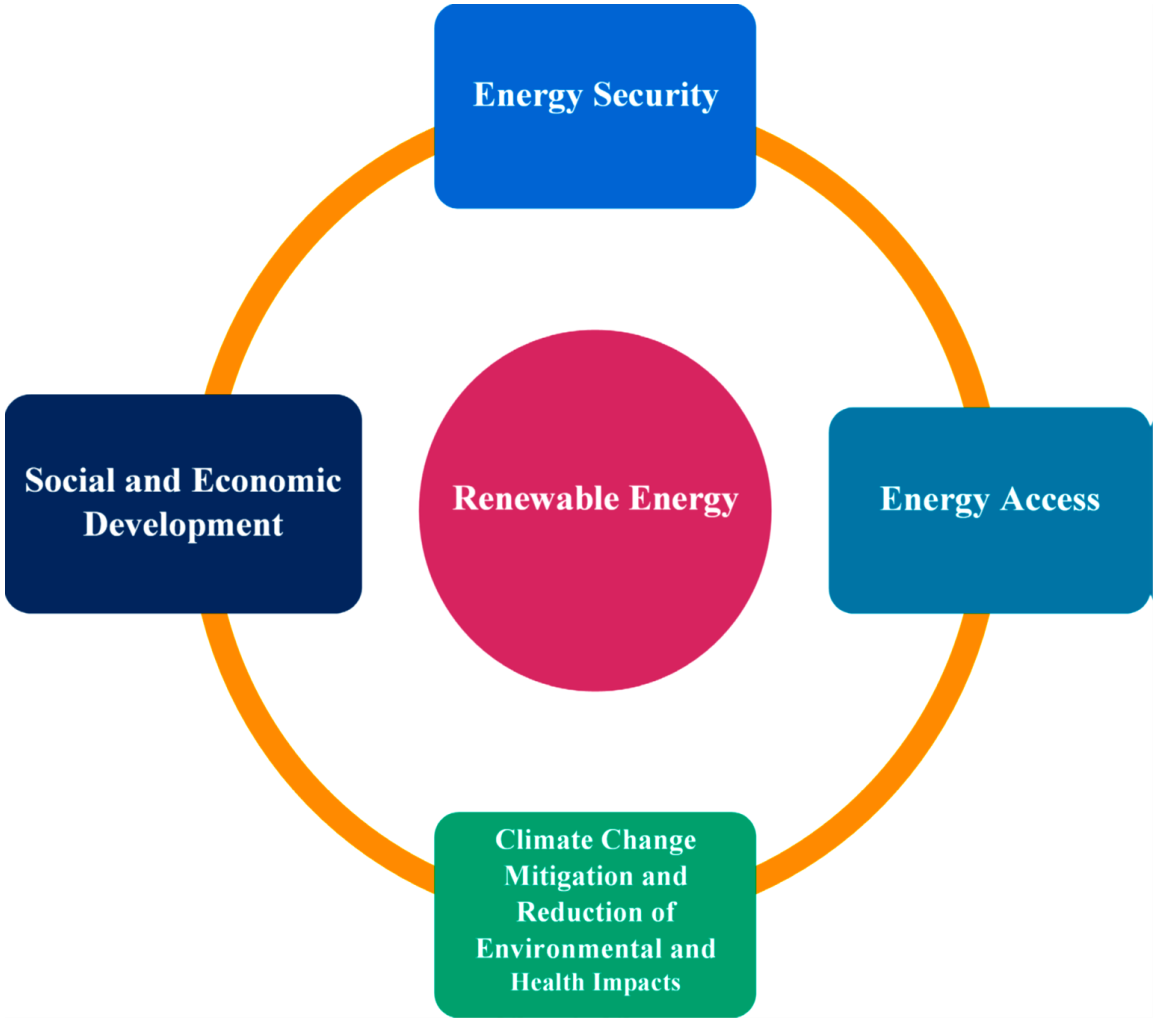
Relationship between renewable energy sources and clean environmental economic growth among South Asian economies

- A study investigated the causal relationship between renewable energy sources and clean environmental economic growth among South Asian economies.
- This study comprised the panel data sets for eight (8) South Asian countries, and data start from 2003 to 2017.
- Reported that the production of renewable energy has compelled an effect on economic growth.
- Hydropower, geothermal, wind, and solar, have valuable and considerable influence on the economic growth of South Asian economies.
- The obtained results reveal that renewable energy sources show a momentous effect on the economic growth of South Asian economies (Anser et al., 2021).

Renewable energy and sustainable development

Renewable energy has a direct relationship with sustainable development through its impact on human development and economic productivity provide opportunities in

- energy security,
- social and economic development,
- energy access,
- climate change mitigation and reduction of environmental and health impacts (Asumadu-Sarkodie & Owusu, 2016).



Opportunities of renewable energy sources towards sustainable development

Energy security

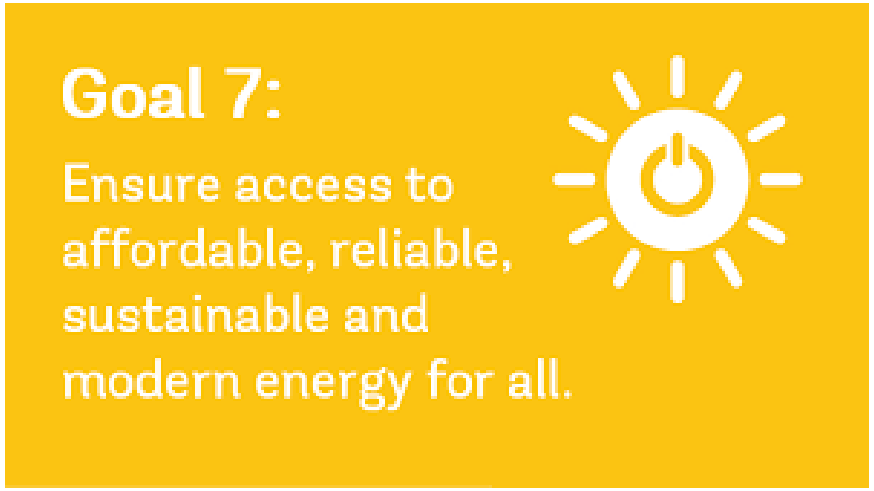
- The concern in energy security is based on the idea that there is a continuous supply of energy which is critical for the running of an economy
- Renewable energy sources are evenly distributed around the globe as compared to fossils and in general less traded on the market.
- Renewable energy reduces energy imports and contribute diversification of the portfolio of supply options and reduce an economy's vulnerability to price volatility and represent opportunities to enhance energy security across the globe.
- The introduction of renewable energy can also make contribution to increasing the reliability of energy services, to be specific in areas that often suffer from insufficient grid access.
- A diverse portfolio of energy sources together with good management and system design can help to enhance security.

Social and economic development

- Generally, the energy sector has been perceived as a key to economic development with a strong correlation between economic growth and expansion of energy consumption.
- Creates employment; renewable energy study in 2008, proved that employment from renewable Energy technologies was about 2.3 million jobs worldwide, which also has
  - improved health, education, gender equality and environmental safety.

Energy access

Sustainable Development Goal 7



This can be achieved with renewable energy source since they are generally distributed across the globe.

Climate change mitigation and reduction of environmental and health impacts

- Renewable energy sources used in energy generation helps to
  - reduce greenhouse gases which mitigates climate change,
  - reduce environmental and health complications associated with pollutants from fossil fuel sources of energy.

Certain shortcoming of renewable energy exists such as:

- The discontinuity of generation due to seasonal variations as most renewable energy resources are climate-dependent,
  - that is why its exploitation requires complex design, planning and control optimization methods.
- Fortunately, the continuous technological advances in computer hardware and software
  - are permitting scientific researchers to handle these optimization difficulties using computational resources applicable to the renewable and sustainable energy field.

Challenges affecting renewable energy sources

- Disruptive alterations in all energy systems are necessary for tapping widely available renewable Energy sources.
- Organizing the energy transition from non-sustainable to renewable energy is often described as the major challenge of the first half of the twenty-first century
- A major barrier towards the use of renewable energy source depends on a country's policy and policy instrument which in turn affect the cost and technological innovations.
- Technological innovations affect the cost of renewable energy technologies which in turn leads to market failures and low patronization of the renewable energy technology.
  - In the light of this, an effective renewable energy policy should take the interconnection of factors affecting renewable energy supplies and sustainability into consideration.
- The cost, price, political environment and market conditions have become barriers preventing developing, least developed and developed countries to fully utilize its potentials.

Challenges that tend to hinder the sustainability of renewable energy sources and its ability to mitigate climate change.

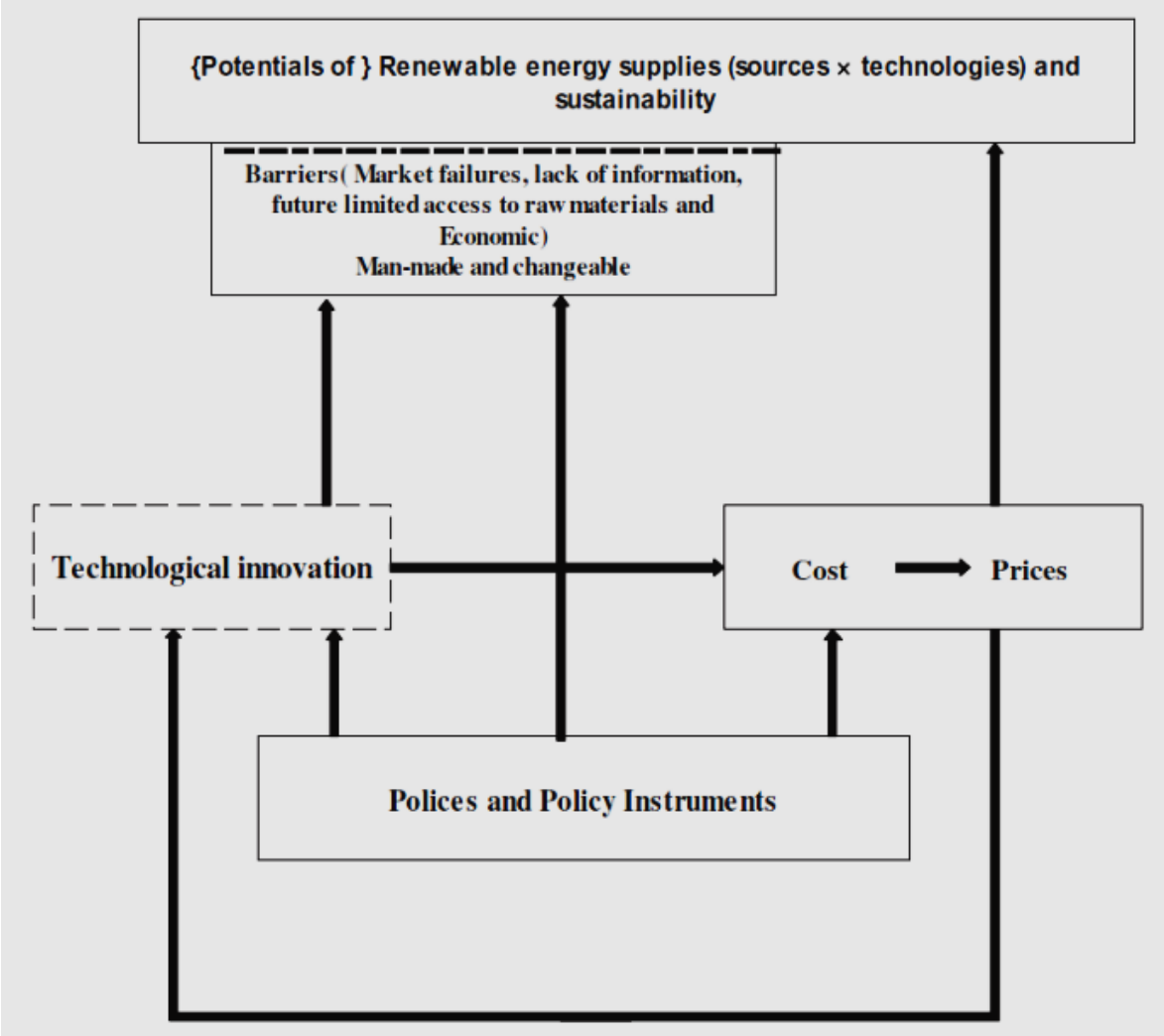
- market failures,
- lack of information,
- access to raw materials for future renewable resource deployment,
- and most importantly our (humans) way of utilizing energy in an inefficient way.

Suggestions to improve the concerns of renewable energy being sustainable and also reduce the rate of the depletion of the ozone layer due to the emissions of GHG especially carbon dioxide (CO_2)

- Formulation of policies and discussions from all sectors towards the improvement of technologies in the renewable sector to sustain them.
- Changes in our use of energy in a more efficient way as individuals, countries and the world as a whole.
- Increase research in these areas, so that the fear of some renewables posing risks in the future is limited.
- Improve education, awareness-raising and human institutional capacity on climate change mitigation, adaptation, impact reduction and early warning (Owusu & Asumadu-Sarkodie, 2016)

Policy recommendations according that can help mitigate climate change and its impacts

- All sectors and regions have the potential to contribute by investing in Renewable energy technologies and policies to help reduce it.
- Reducing our carbon footprint (**the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions**) through the changes in lifestyle and behaviour patterns can contribute a great deal to the mitigation of climate change.
- Research into innovations and technologies that can reduce land use and also reduce accidents from renewable energy sources and the risk of resource competition,
  - for example in Bioenergy where food for consumption competing with energy production.
- Enhancing international cooperation and support for developing countries towards the expansion of infrastructure and upgrading technology for modern supply and sustainable energy services as a way of mitigating climate change and its impacts (Owusu & Asumadu-Sarkodie, 2016)



Interconnection of factors affecting renewable energy supplies and sustainability, adapted from Edenhofer et al. (2011); Verbruggen et al. (2010) (Owusu & Asumadu-Sarkodie, 2016)

- To prepare for an urban influx of 2.5 billion people by 2050,
  - it is critical to create cities that are low carbon, resilient, and livable.
- Cities not only contribute to global climate change by emitting the majority of anthropogenic greenhouse gases but also are particularly vulnerable to the effects of climate change and extreme weather.
- Through technical advancements in power density, **city-integrated renewable energy will be better suited to satisfy the high-energy demands of growing urban areas**.
- Several economic, technical, behavioral, and political challenges need to be overcome for innovation to improve urban sustainability.

Applications of renewable energies

- Provision of final or useful energy using renewable energies is based on energy flows originated by the
  - movement and gravitation of planets (i.e. tidal energy),
  - heat stored and released by the earth (i.e. geothermal energy) and
  - in particular energy radiated by the sun (i.e. solar radiation)

- There is thus a great variety of renewable energies in terms of energy density, variations of the available forms of energy and the related secondary or final energy carriers and final energy to be provided.

Structure and procedure

Due to the great variety of possibilities to use renewable energy sources with the aim to fulfill the demand for end or useful energy, *it is very difficult to present the different possibilities in a similar manner.*

- It is thus highly important to explain the different utilization methods in a **flexible manner.**

Structure & Procedures (Principles)

The possibilities and boundaries to convert renewable energies into end or useful energy largely depend on the respective physical and technical conditions.

Efficiency: the ratio of useful power output (e.g. electricity, heat) to the power input (e.g. solar radiation, geothermal energy).

It depends on the respective operating conditions of the conversion plant, as well as a series of other factors, which vary over time .

Utilization ratio: the ratio of the total output of useful energy to the total energy input within a certain period of time (e.g. one year).

The observed time periods may include part load periods and breaks as well as start-up and shutdown times.

Technical availability: describe the portion of the time period under observation, within which a plant has actually been available for its intended purpose and thus considers time periods during which the plant has been unavailable due to malfunctions.

Importance of Renewable Energy Resources and Technologies for Sustainable Development

i) They have much less environmental impact compared to conventional sources of energy.

ii) Renewable energy sources can not be depleted unlike fossil fuel and uranium resources.

iii) They favour power system decentralization and locally applicable solutions more or less independent of the national network, thus, enhancing the flexibility of the system and the economic power supply to small isolated settlements.

M. K. Anser, M. S.Shabbir , M.Tabash, S.H. A. Shah, M. Ahmad, M. Y. Pengand, L. B. Lopez. Do renewable energy sources improve clean environmental economic growth? Empirical investigation from South Asian economies. 2021. Energy Exploration & Exploitation. 39(5) 1491–1514.

P. A. Owusu & S. Asumadu-Sarkodie (2016). A review of renewable energy sources, sustainability issues and climate change mitigation. Cogent Engineering, 3:1, 1167990, DOI: 10.1080/23311916.2016.1167990.