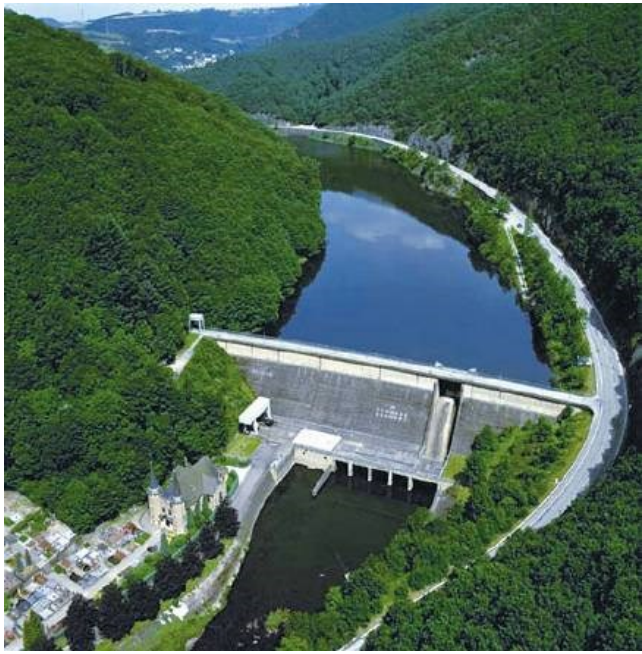
Renewable Energy and Photovoltaic Power Systems (ENEE5307)



Faculty of Engineering & Technology
Department of Electrical & Computer Engineering

Course Information	
Course Title	**Renewable Energy and Photovoltaic Power Systems** **Compulsory for Power Concentration**
Course Number	**ENEE5307**
Prerequisites	**Electrical Machines and Power Electronics**
Instructor	**Nasser Ismail (nismail@birzeit.edu)**
Office Location	**Masri220**
Class Hours	**M,W 12:50-14:05**

Objectives & Intended Learning Outcome

- By the end of this course, students will be :
- Familiar with the basic concepts of traditional and renewable energy systems.
- Familiar with solar resource and photovoltaic fundamentals and details
- Able to understand operation and compare between different types of PV cells, arrays and panels
- Able to design and integrate different components of PV systems
- Familiar with wind resources and energy systems
- Familiar with different components of wind energy systems
- Perform site survey and pre-plan for wind and PV energy systems
- Able to size wind and PV systems and assess and compare their cost and economic aspects

Course Outcomes (According to ABET a-k)

- Upon completion of the course the students will have:
- (a) An ability to apply knowledge of mathematics, science, and electrical engineering
- (c) An ability to design a system, component, or process to meet desired needs
- (k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Course Contents

- Energy Fundamentals
- Renewable Energy Sources and Systems
- Photovoltaic Fundamentals
- PV Systems, detailed study of their main components:
  - Solar radiation
  - Semiconductor basics and pn junctions
  - Solar cell technologies and efficiency limits

Course Contents

- PV System basics and design
- PV system components and configurations
- Modules and arrays
- PV Batteries,
- PV Inverters
- Chargers, charge controllers and Maximum Power Point Trackers
- PV system related specifications and system design constraints

- Wind resource
- Wind energy systems and their basic components,
- Electrical generators for wind energy systems
- System Sizing and Economics of PV and wind systems
- Site survey and pre-planning

- Main Reference: Renewable and Efficient Electric Power Systems by Gilbert M. Masters, Wiley, Second Edition 2013

Additional References			
[1]	**Photovoltaic systems** **James P. Dunlop** **2nd edition** **ATP 2010**	[2]	**Wind and solar power systems : design , analysis , and operation** **Mukund R. Patel** **2nd edition; CRC 2005**
[3]	**Grid converters for photovoltaic and wind power systems** Teodorescu ‹Remus 2011	[4]	**Photovoltaic systems engineering** **Roger A. Messenger, Jerry Ventre** **3rd edition** **CRC Press 2010**
[5]	**Power generation technologies** Breeze ‹Paul A 2005	[6]	**Solar photovoltaic project development** Wade, Herbert A. 2003

Grading Scheme		
Assessment Type	**Date**	**%**
Midterm Exam (or short exams)		**30 %**
Individual Assignment		**10%**
Group project		**20 %**
Final Exam		**40 %**

Note: Details of project and assignments will be provided separately

2-3

Simulation → PVsyst.

→ Mechanical Drawing software
sketchup, Autocad

1165454 _ Ahmad Ahmad

Introduction

مقولة مشهورة

We do not inherit the Earth from our parents

we borrow it from our children.

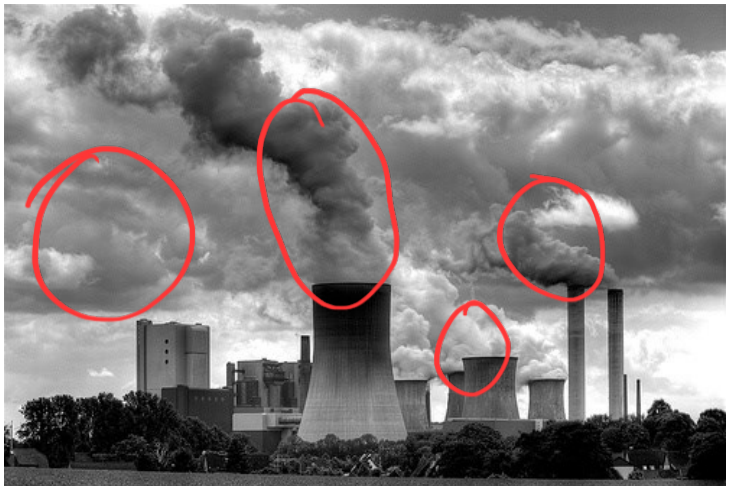
- In 2019 Human population was 7.67 billion
- http://www.worldometers.info/world-population/
- Increasing energy demands
- Increasing population and lack of traditional resources

fossil fuel

What's wrong with this picture?

- Pollution from burning fossil fuels leads to an increase in greenhouse gases, acid rain, and the degradation of public health.
- There is 36 million tons of carbon dioxide emitted in the world
- China is the world's largest Emitter of CO_2 (25%) , followed by USA (15%), EU-28(10%) ; India (7%); Russia (5%) CO_2
- The USA has contributed most to global CO_2 emissions to date, accounting for 25% of cumulative emissions. This is followed by the EU-28 (22%); China (13%); Russia (6%) and Japan (4%).

- In 2005, the U.S. alone emitted 2,513,609 metric tons of carbon dioxide, 10,340 metric tons of sulfur dioxide, and 3,961 metric tons of nitrogen oxides from its power plants.



Background

- In 1831, Michael Faraday's many years of efforts rewarded when he discovered electromagnetic induction
- Later, he invented the first generator
- Today, electric energy technologies have a central role in social and economic development at all scales
- Energy is closely linked to environmental pollution and degradation, to economic development and quality of life
- Today, we are mostly dependent on nonrenewable fossil fuels that have been and will continue to be a major cause of pollution and climate change
- Finding sustainable alternatives is becoming increasingly urgent

Renewable Energy

- **Renewable energy** is energy that comes from resources which are continually replenished at a rate higher than their consumption.
- Types of renewable energy includes:
  - solar energy
  - wind energy
  - the power from living things: biomass
  - the power from moving water: hydro/micro-hydro and tidal waves
  - Earth's heat
- Remember, all sources of energy, including renewable sources, affect the environment

Sustainable Energy الطاقة المستدامة

- Sustainable Energy: is the sustainable

provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs.

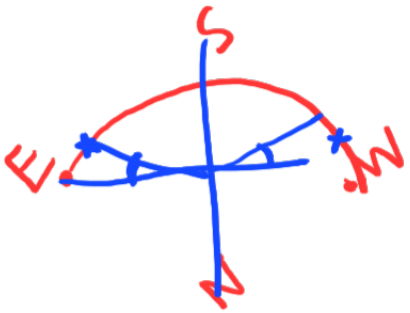
مفهوم استدامة الطاقة يعني توفير الطاقة التي تلبي احتياجات الحاضر دون المساس بقدرة الأجيال المقبلة على تلبية احتياجاتها.

- Technologies that promote sustainable energy include renewable energy sources, and also technologies designed to improve energy efficiency.

Solar Energy - Power from the Sun

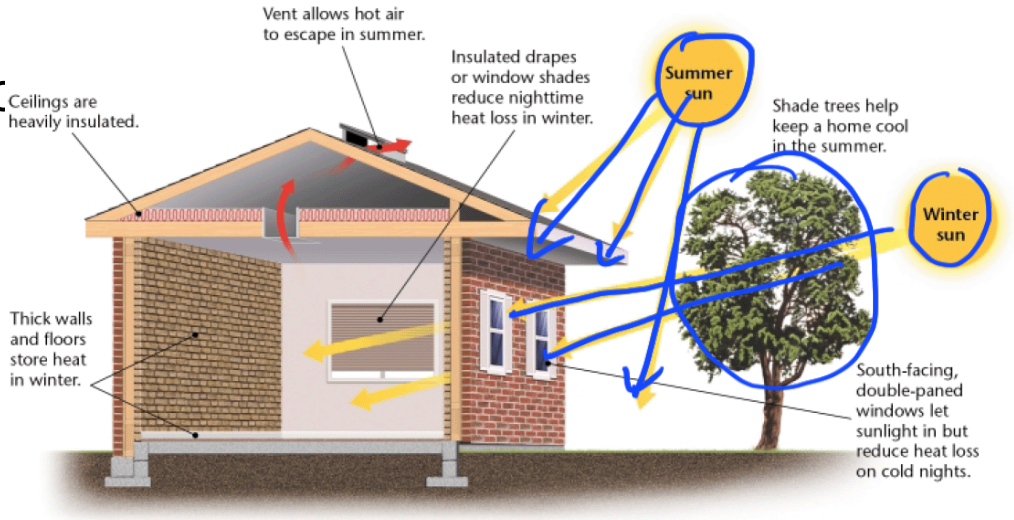
- Most renewable energy comes either **directly** or **indirectly** from the sun.
- **Direct solar** energy is used every day, like when the sun shines on a window and heats the room
- Solar energy can also be used **indirectly** to generate electricity in solar cells

$\frac{10}{24} \times 360$



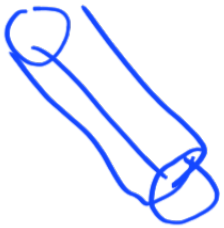
Passive solar heating/cooling

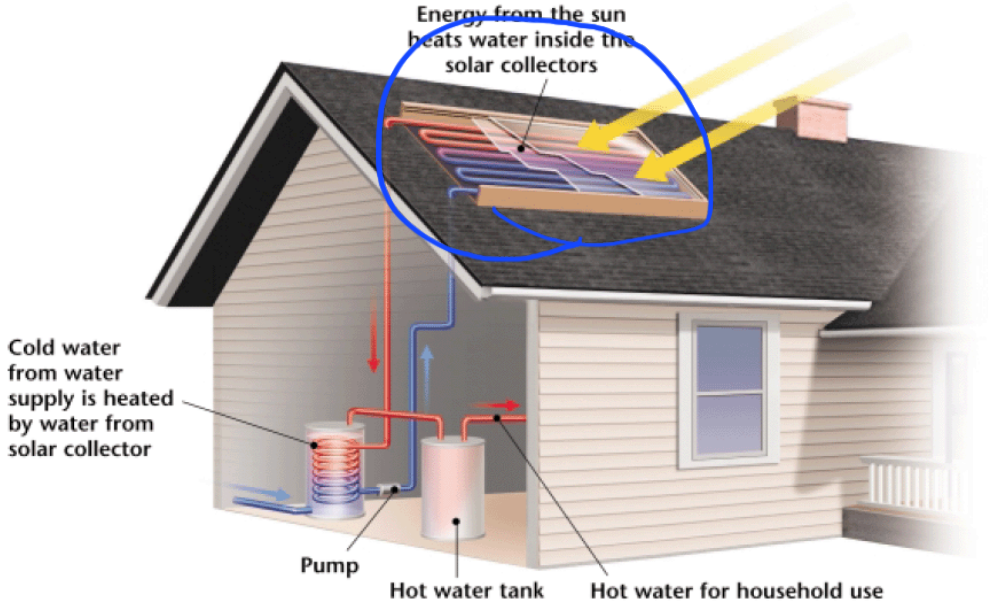
- Passive solar heating is the use of sunlight to heat buildings directly
- In the Northern Hemisphere, south facing windows receive the most solar energy
- Therefore, passive solar buildings have large windows that face south
- Trees – A house shaded by trees is a much cooler house during the summer. Also, keep in mind that during the winter, the leaves are gone off most types of trees, so the winter sun can still shine into the home.
- An average household cc
of the passive solar featu



Active solar heating

- Active solar heating is the gathering of solar energy by collectors that are used to heat water or heat a building
- Solar collectors, usually mounted on a roof, capture the sun's energy
- A liquid is heated by the sun as it flows through solar collectors
- The hot liquid is then pumped through heat exchangers, which heat





Photovoltaic cells

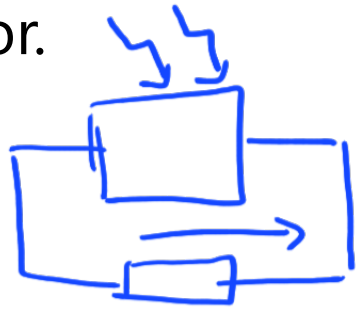
- Photovoltaic cells are solar cells that convert the sun's energy into electricity.
- Solar cells have no moving parts, and they run on nonpolluting power from the sun.
- However, they produce a very small electrical current. Meeting the electricity needs of a small city would require covering hundreds of square kilometers with solar panels.

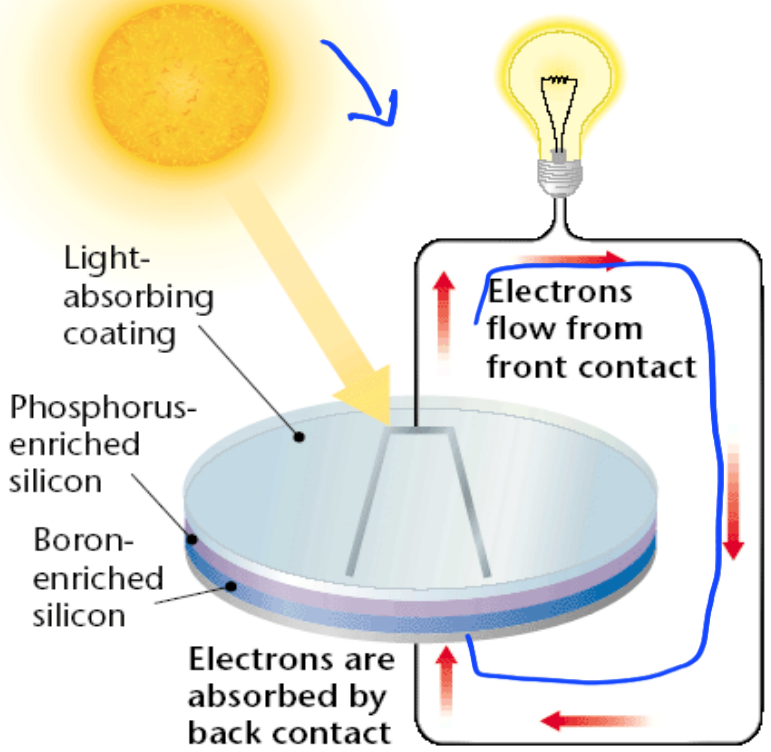
End of L1
22/2/2021

L2_ONLINE
24/2/2021

Photovoltaic cells

- Sunlight falls on a semiconductor, causing it to release electrons.
- The electrons flow through a circuit that is complete when another semiconductor in the solar cell absorbs electrons and passes them on to the first semiconductor.





Photovoltaic cells

- Solar cells require extended periods of sunshine to produce electricity.
- This energy can be stored in batteries, which supplies electricity when the sun is not shining.
- Currently, solar cells provide energy for more than 1 million households in developing countries, where energy consumption is minimal and electricity distribution networks are limited.

Wind power

- Energy from the sun warms the Earth's surface unevenly, which causes air masses to flow in the atmosphere.
- We experience the movement of these air masses as wind.
- Wind power, which converts the movement of wind into electric energy, is the fastest growing energy source in the world.

Wind farms

- Wind turbines are used to capture the energy from the wind.
- Large arrays of wind turbines are called wind farms. Large wind farms supply electricity to thousands of homes.
- In windy rural areas, small wind farms with 20 or fewer turbines are also becoming common.
- Because wind turbines take up little space, some farmers can add wind turbines to their land and still use the land for other purposes.

Wind: an underdeveloped resource

- Scientists estimate that the windiest spots on Earth could generate more than ten times the energy used worldwide.
- The electricity From wind farms can be used to produce hydrogen from water.
- Today, most of the large energy companies are developing plans to use more wind power.

Biomass: power from living things

- Biomass fuel consists of plant material, manure سماد, or any other organic matter that is used as an energy source.
- Fossil fuels (وقود احفوري) can be thought of as biomass energy sources, although they are nonrenewable.
- Renewable biomass fuels, such as wood and dung (روث الحيوانات), are major sources of energy in developing countries.
- More than half of all wood cut in the world is used as fuel for heating and cooking.

Biomass: power from living things

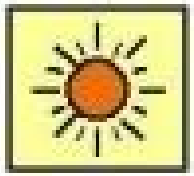
- Although materials like wood are a renewable resource, if trees are cut down faster than they grow, the resulting deforestation, and soil erosion can be severe.
- In addition, harmful air pollution may result from burning wood and dung.

Biomass →

Methane

- When bacteria decompose organic wastes, one byproduct is methane gas.
- Methane can be burned to generate heat or electricity.
- In China, more than 6 million households use biogas digesters to ferment (تخمير)manure and produce gas for heating and cooking.
- It is possible to generate electricity by using the methane from the decomposition of trash.

Biogas Cycle



Solar energy

Photosynthesis

Animal husbandry

Biofuel production

Crop harvesting

Industrial processing

Human consumption

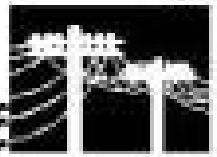
CO_2

H_2O

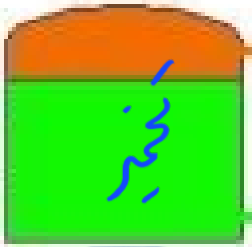
Energy crops

Biofertilizer

Electrical and/or thermal energy



Organic wastes



Anaerobic digestion

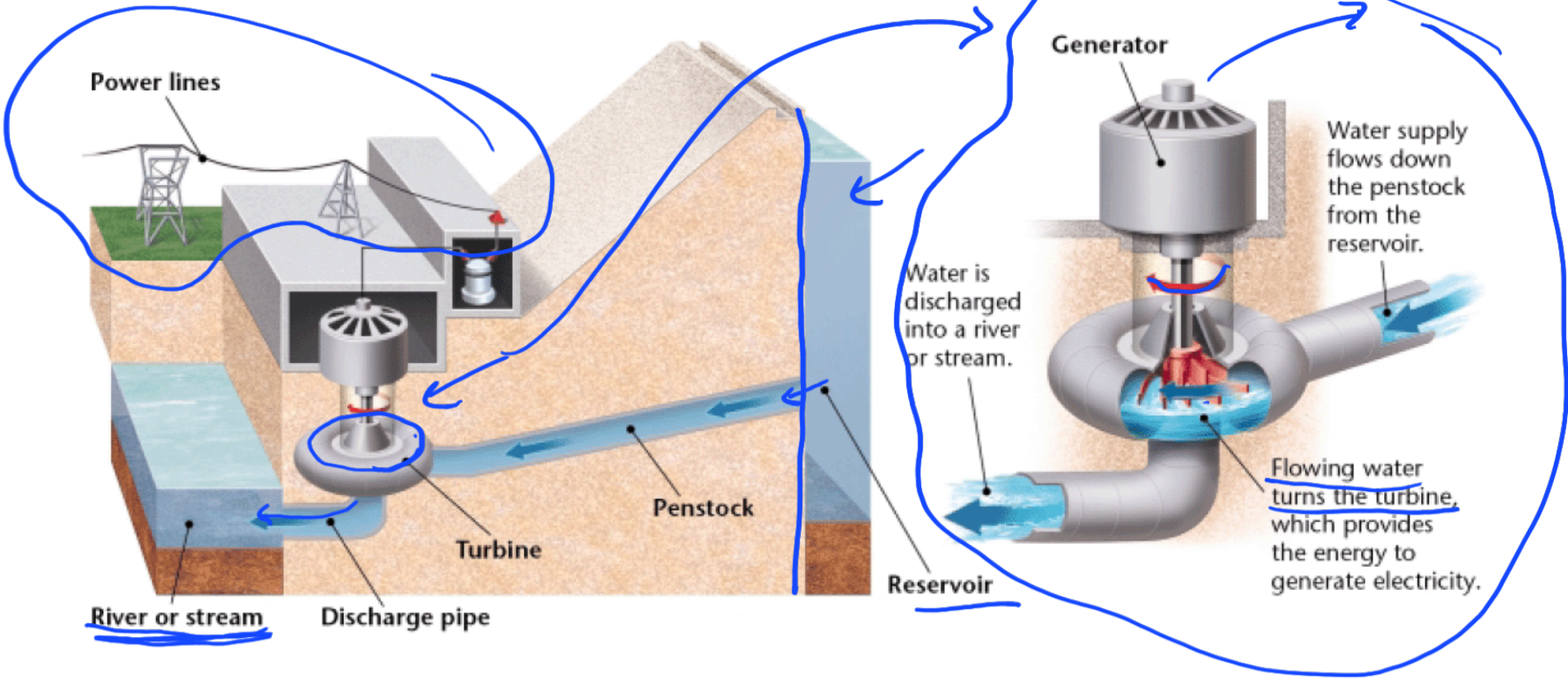
Biogas

Natural gas pipeline

Hydroelectricity: power of moving water

- Hydroelectric energy is electrical energy produced by falling water.
- Hydroelectric energy accounts for 20% of the world's electricity.
- Large hydroelectric power plants have a dam that is built across a river to hold back a reservoir of water.
- The water in the reservoir is released to turn a turbine, which generates electricity.

Hydroelectricity: power of moving water



The benefits of hydroelectric energy

- Hydroelectric dams are expensive to build, but relatively inexpensive to operate.
- Unlike fossil fuel plants, hydroelectric dams do not release air pollutants that cause acid rain and precipitation.
- Hydroelectric dams also tend to last much longer than fossil fuel-powered plants.
- Dams also provide other benefits such as flood control and water for drinking, agriculture, industry, and recreation.

The disadvantage of hydroelectric energy

- A dam changes a river's flow, which can have far-reaching consequences.
- When the land behind a dam is flooded, people are often displaced. If a dam bursts, people living in areas below the dam can be killed.
- River sediments build up behind the dam instead of enriching land farther down the river, making farmland below the dam less productive.
- Recent research has also shown that the decay of plant matter trapped in reservoirs can release large amounts of greenhouse gases-sometimes more than a fossil-fuel powered plant.

Modern trends

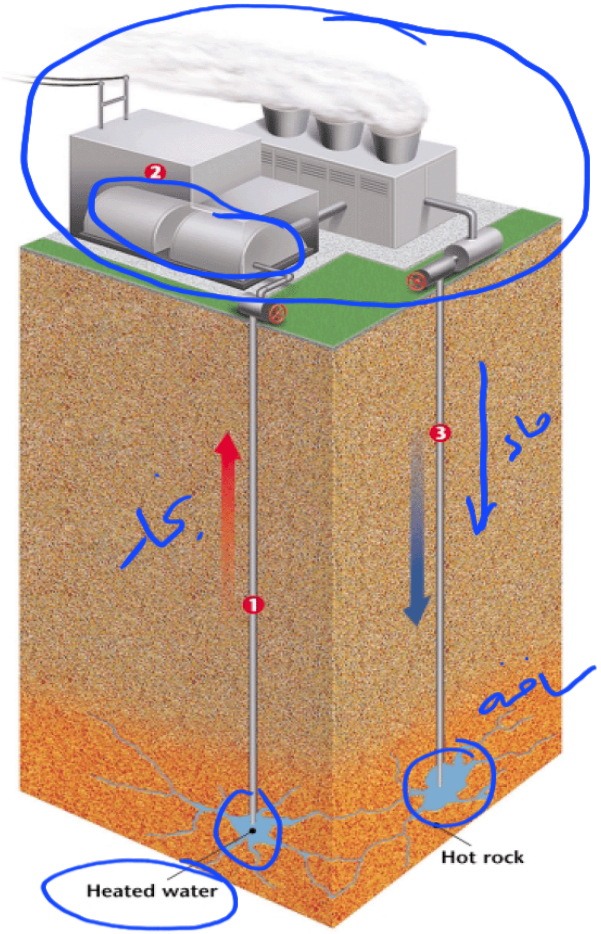
- In developing countries the construction of large dams continues
- One modern trend is micro-hydropower, which is electricity produced in a small stream without having to build a big dam. The turbine may even float in the water, not blocking the river at all.
- Micro-hydropower is much cheaper than large hydroelectric dam projects, and it permits energy to be generated from small streams in remote areas.

Geothermal energy: power from the earth

- In some areas, deposits of water in the Earth's crust are heated by geothermal energy.
- Geothermal energy is the energy produced by heat within the Earth.
- The United States is the world's largest producer of geothermal energy.
- Although geothermal energy is considered a renewable resource, the water that is used must be managed carefully so that it is not depleted.

Geothermal energy: power from the earth

- Geothermal power plants generate electricity using the following steps:
  - Steam rises through a well
  - Steam drives turbines, which generate electricity
  - Leftover liquid is pumped back into the hot rock
  - The leftover liquid, water, is returned to Earth's crust because it can be reheated by geothermal energy and used again.



Why renewable energy?

- There are many energy sources today that are extremely limited in supply.
- Some of these sources include oil, natural gas, and coal. It is a matter of time before they will be exhausted.
- Estimates are that they can only meet our energy demands for another fifty to seventy years.
- So in an effort to find alternative forms of energy, the world has turned to renewable energy sources as the solution.
- There are many advantages and disadvantages to this

Renewable energy: advantages

- One major advantage with the use of renewable energy is that as it is renewable it is therefore sustainable and so will never run out.
- Even more importantly, renewable energy produces little or no waste products such as carbon dioxide or other chemical pollutants, so has minimal impact on the environment.
- Renewable energy facilities generally require less maintenance than traditional generators. Their fuel being derived from natural and available resources reduces the costs of operation.
- Renewable energy projects can also bring economic benefits to many regional areas, as most projects are located away from large urban centers and suburbs of the capital cities. These economic benefits may be from the increased use of local services as well as tourism.

Renewable energy: disadvantages

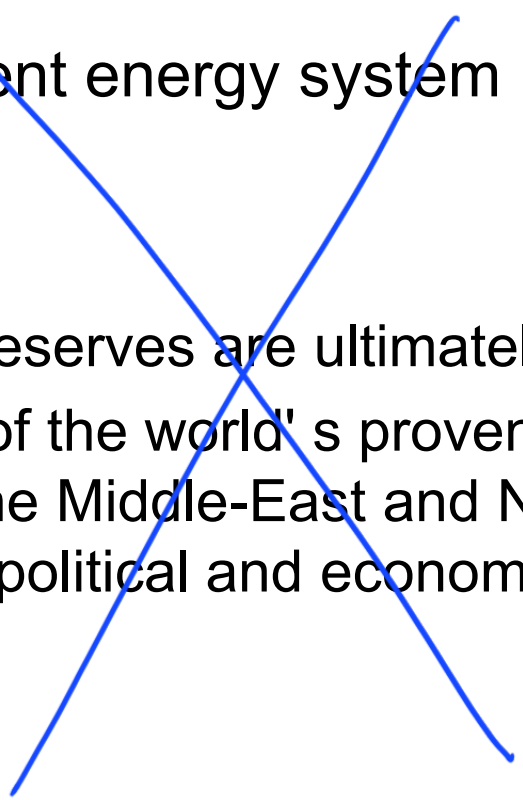
- One disadvantage with renewable energy is that it is difficult to generate the quantities of electricity that are as large as those produced by traditional fossil fuel generators.
- Another disadvantage of renewable energy sources is the reliability of supply.
- Renewable energy often relies on the weather for its source of power.
- Hydro generators need rain to fill dams to supply flowing water.
- Wind turbines need wind to turn the blades, and solar collectors need clear skies and sunshine to collect heat and make electricity.

Renewable energy: disadvantages

- When these resources are unavailable so is the capacity to make energy from them.
- This can be unpredictable and inconsistent.
- The current cost of renewable energy technology is also far in excess of traditional fossil fuel generation , but prices are being reduced.
- This is because it is a new technology and as such has extremely large capital cost (especially R & D costs).

Why Sustainable Energy Matters

- The world's current energy system is built around fossil fuels
  - Problems:
    - Fossil fuel reserves are ultimately finite
    - Two-thirds of the world' s proven oil reserves are located in the Middle-East and North Africa (which can lead to political and economic instability)

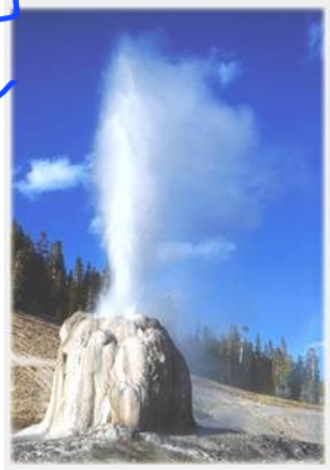


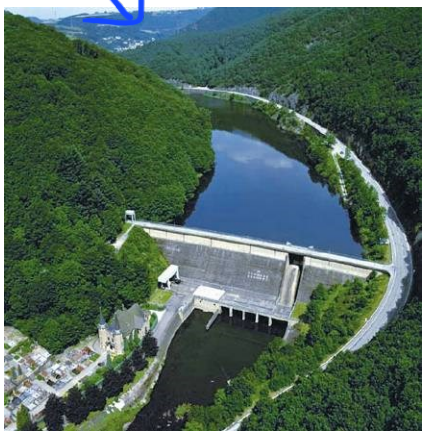
Why Sustainable Energy Matters

- Detrimental environmental impacts
  - Extraction (mining operations)
  - Combustion
    - » Global warming (could lead to significant changes in the world' s climate system, leading to a rise in sea level and disruption of agriculture and ecosystems)

Making the Change to Renewable Energy

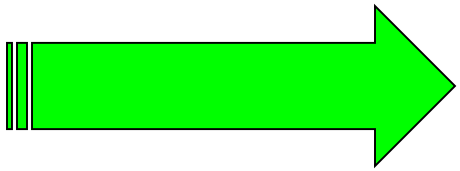
- Solar
- Geothermal
- Wind
- Hydroelectric

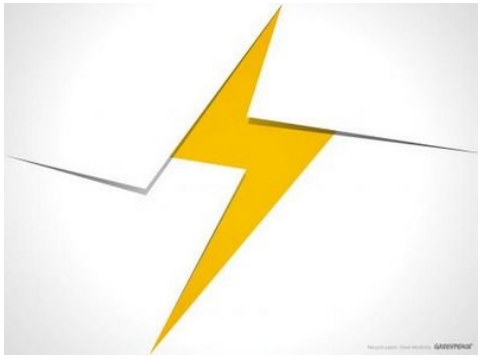




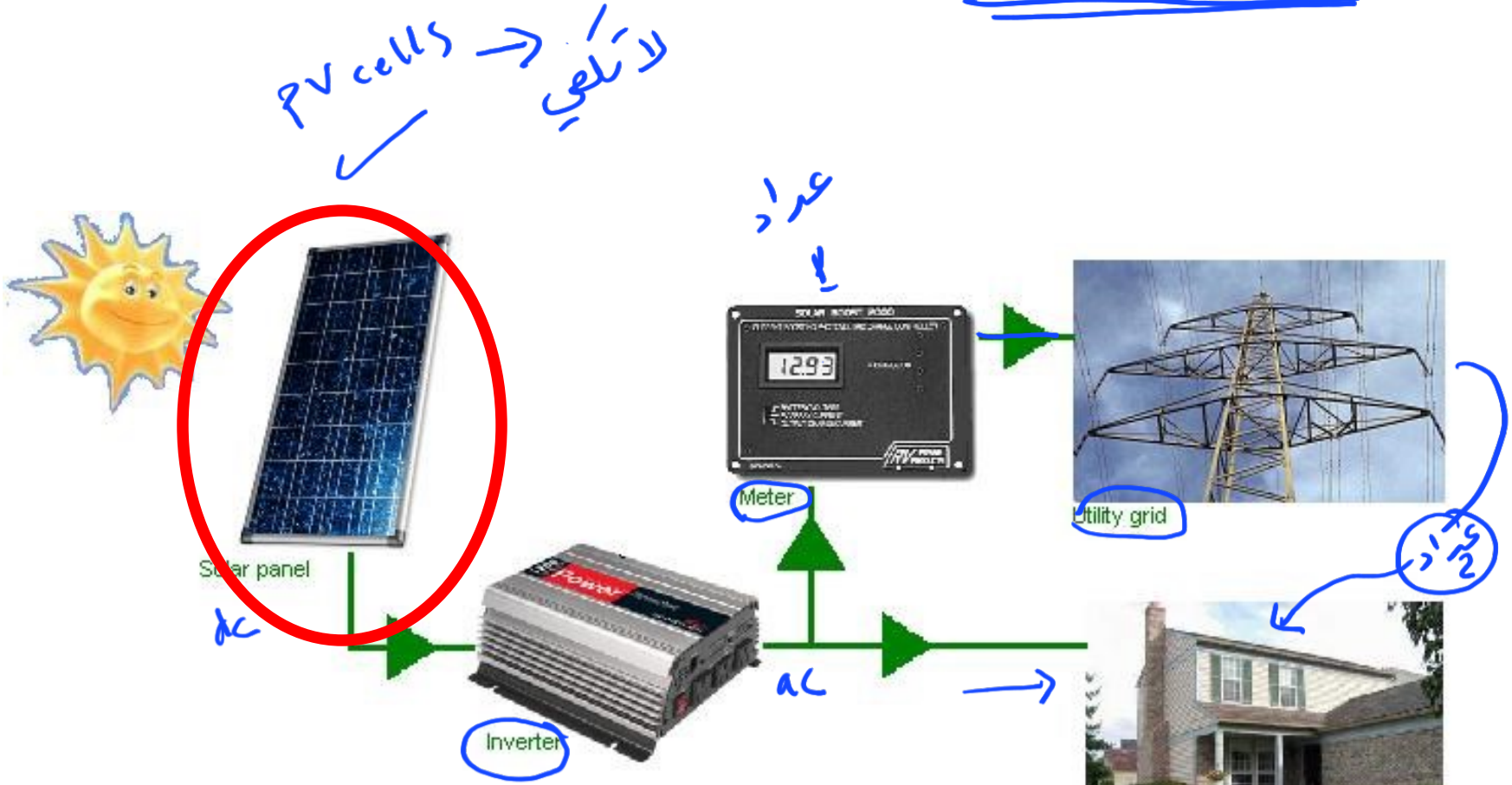
Harnessing the Sun

PV cell





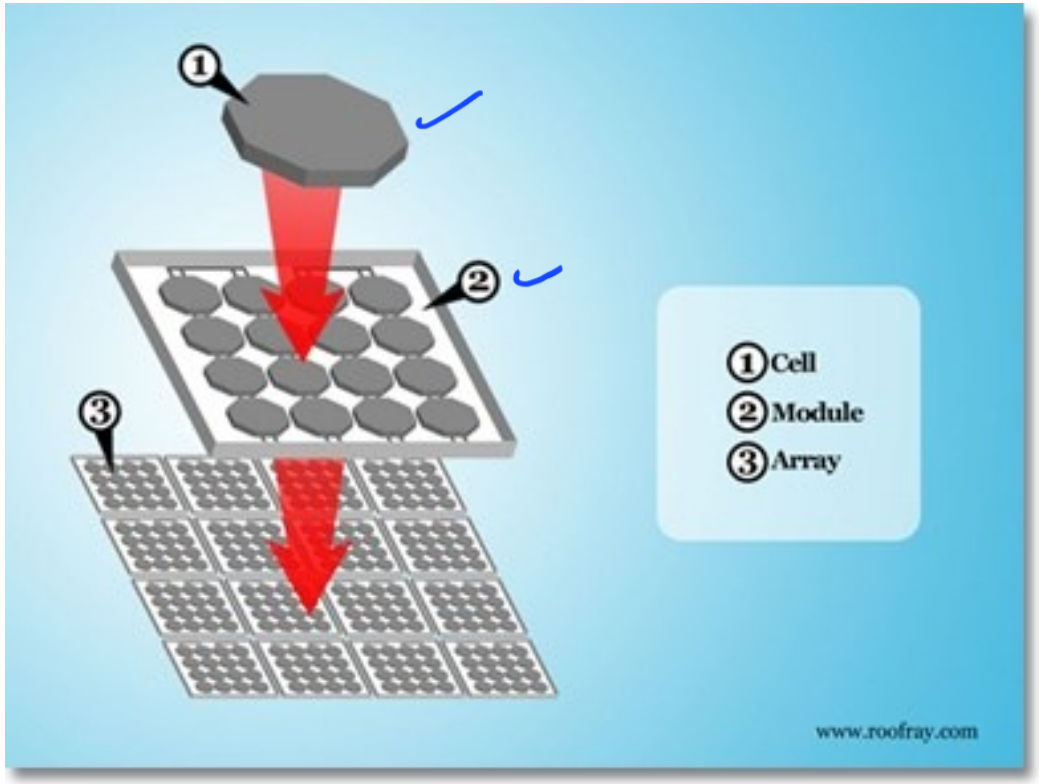
Solar Photovoltaic Systems



Example: Grid Tied Photovoltaic System

Photovoltaic (PV) Hierarchy

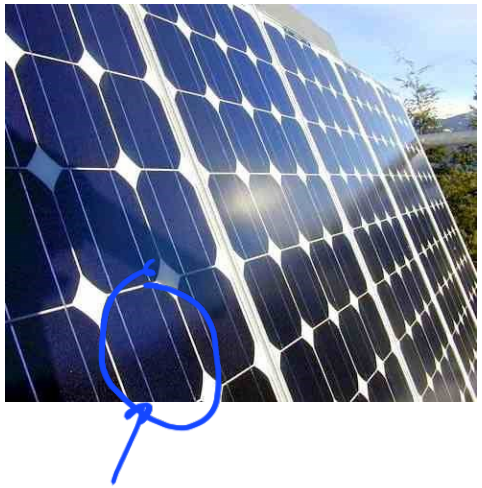
- Cell < Module < Panel < Array



Available Cell Technologies ?

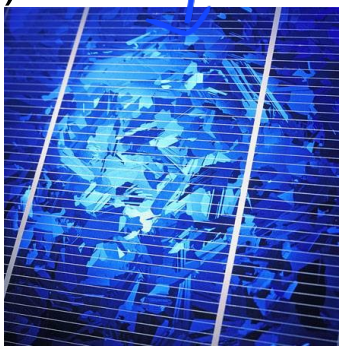
- Single-crystal or Mono-crystalline Silicon
- Polycrystalline or Multi-crystalline Silicon
- Thin film
  - Ex. Amorphous silicon or Cadmium Telluride

Monocrystalline Silicon Modules



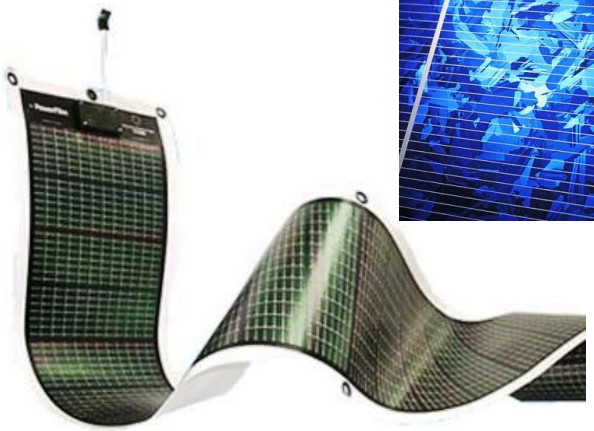
- Most efficient commercially available module (11% - 14%) , Most expensive to produce ,Circular (square-round) cell creates wasted space on module

Polycrystalline Silicon Modules



- Less expensive to make than single crystalline modules
- Cells slightly less efficient than a single crystalline (10% - 12%)
- Square shape cells fit into module efficiently using the entire space

Amorphous Thin Film



- Most inexpensive technology to produce
- Metal grid replaced with transparent oxides
- Efficiency = 6 – 8 %
- Can be deposited on flexible substrates
- Less susceptible to shading problems
- Better performance in low light conditions that with crystalline modules

- In this course we will focus mainly on PV and Wind for electricity generation