Solar Energy

Slide 2: ***Solar Energy: The Sun***

- The sun is the source of all life on planet earth.
- The source of energy in the sun is at its core.
- This energy is released into space primarily as electromagnetic radiation.
- We experience this radiation in the form of heat and light.
- Life exists on our planet because of its distance from the sun, resulting in acceptable average temperatures and the greenhouse effect.
- Earth also has an atmosphere, which protects the surface from harmful rays from the sun.

Slide 3: ***Solar Energy: How powerful is it?***

- Every hour, enough sunlight energy reaches the earth to meet the world's energy demand for a whole year.
- Even though only a percentage of this potential is accessible, it is still enough to provide just under six times the power the world currently requires.
- Remember, this energy is distributed over the complete spherical surface of the earth!
- It is mainly a question of how to convert solar energy as efficiently, sustainably and cost-effectively as possible into electricity and hot water.

- South Africa has the perfect climate for solar energy, one of the best in the world.
- South Africa has on average more than 2 500 hours of sunshine every year.

Slide 4: ***Solar Energy: Types and uses***
There are three different and mostly used forms of solar energy:

1. Solar thermal (ST), for instance domestic solar water heater (SWH), heating temperature below 100^{o}C.
2. Concentrated solar Power (CSP). This typed is used to produce very high temperatures, for heating to temperatures above100^{o}C. The heat can then also be used to produce steam that can be used to produce electricity using steam turbines.
3. Solar electric, for instance photovoltaic (PV). This type is used to produce electricity from direct sun light using photovoltaic cells.

Slide 5*: Solar Water Heating:*
- There are two main types of solar water heaters, Namely:
    1. Flat plate collector.
    2. Evacuated tube collector.

Flat Panel collector

How it works:
- A flat panel solar water heater is a ”BOX” with a glass cover.
- Inside is a series of copper tubes attached to a sheet metal absorber.
- The sheet metal absorber is coated in a black substance designed to capture the sun’s rays – this is called selective surface. Black paint can also be used.
- The collector has isolation in the back and on the sides, to prevent the heat from being lost to ambient temperature.
- Via the absorber, the sun rays heat up the water which circulates from the collector to an insulated tank, ready to be used.
- It can be used for anything from heating domestic hot water and living spaces, to heating swimming pools.
- Sometimes the panels are also used for solar-assisted cooling, industrial processes and the desalination of drinking water.

Slide 6: ***Solar Water Heating: Evacuated Tube Collector***
- Consists of multiple evacuated glass tubes with solar absorbers that collect the heat energy from the sun.
- The vacuum between the inner and outer tubes serves as a form of insulation to minimise heat loss.
- The absorber inside the vacuum tube absorbs the radiation from the sun and heats up the heat transfer fluid inside the copper pipe via conductive heat transfer fins.
- Additional radiation is picked up from the reflector behind the tubes.
- Whatever the angle of the sun, the round shape of the vacuum tube allows it to reach the absorber.

- Even on a cloudy day, when the light is coming from many angles at once, the vacuum tube collector can still be effective.

Slide 7: *Solar Water Heating: Direct vs. Indirect*

There are two main ways of heating water in a solar water heater:

1. **Indirect system:**
   - Indirect systems use a heat transfer fluid (typically mixture of water and ethylene glycol) to move the heat from the solar collector to the tank.
   - The solar loop of indirect systems is freeze resistant, but they have a higher capital cost compared to direct systems.
2. **Direct system:**
   - Direct systems heat the water that is consumed or stored in the collector.
   - Direct systems should be limited to warm climates or those areas that experience only a couple of freezing days per year as the water freezing in the pipes can damage the system.

Slide 8: *Solar Water Heating: Direct vs. Indirect*

In direct systems, the water circulation through the collector can be realized by two ways:

2.1 Active system:
- An active system has a solar water heating system with a circulation pump to transfer heat from the collector to the solar storage tank.

2.2 Passive system:
- The system uses no pump or control system, but natural circulation (thermosiphon). Differences in the temperature of the water cause circulation between the heated water in the solar collector and the storage tank.

- Electrical water heating accounts for a large portion of the energy use in the average South African household.
- Comes mainly from electricity derived from fossil fuels and releases four and a half tons of CO_2 per year.
- If solar energy were to be used instead, households would not only save money, but also electricity, which would in turn benefit the environment in which we live.

Slide 9: *Concentrated Solar Thermal Power Plants (CSP): Concentrated Solar Energy*

- Concentrated Solar Thermal Power Plants (CSP) make use of concentrated solar energy.
- Solar energy can be concentrated onto a point or line receiver with the following technologies:
  a. Parabolic Trough
  b. Fresnel
  c. Parabolic Dish
  d. Central Receiver

Slide 10: *Concentrated Solar Thermal Power Plants (CSP): Converting Solar Energy (Heat) into Electricity*

- A concentrated solar thermal power plant (CSP) converts solar heat into electricity.
- The temperature in a concentrated solar thermal power station is high enough to produce steam.
- The steam is fed into a steam turbine which drives an electric generator to generate electricity.
- Similar systems are used in coal and nuclear power stations, where coal and nuclear energy are used to produce the heat.

Slide 11: *Concentrated Solar Thermal Power Plants (CSP): Examples*

- Fresnel
- Parabolic dish
- Central receiver
- Parabolic trough

Benefits:

- Using solar energy from the sun does not cause pollution.
- Solar energy is a renewable resource, so it will never run out.
- Fossil fuels are conserved, thus limiting harmful emissions and climate change
- The energy of the sun is free and it can be used whenever the sun is shining, from your back garden right up into space.
- Thermal storage (heat) makes it possible for solar thermal power stations to generate electricity at night.
- CSPs can deliver dispatchable electricity 24/7 because of the heat storage.

Problems:

- The electricity-generation costs of solar thermal power stations are still high, but the more the technology is developed, the cheaper it becomes, especially in light of the fact that the fuel, the sun, is free of charge.

Slide 13: Concentrated Solar Thermal Power Plants in South Africa

- The first bidding round of the Renewable Energy Independent Power Producer Procurement Programme started in 2011.
- Up to date four bidding rounds have been completed.
- The following website contains a map which provides the details of each REIPPPP project in South Africa: http://energy.org.za/knowledge-tools/map-of-sites

The following details can be viewed on the website:

- **Name** of the project
- Type of **technology** being build
- The **capacity** of the power plant and the
- Current **status** of the project

Bidding rounds	Capacity allocated (MW)	Number of Projects
Window 1	150	2
Window 2	50	1

Window 3	200	2
Window 3.5	100	1
Window 4&4b	-	-
Total	**500MW**	**6**

Slide 14: ***Photovoltaic Panels: Photovoltaic Effect***

- Converting solar energy into electrical energy by means of solar cells is known as the photovoltaic effect
- A solar panel consists of a group of solar cells, which convert solar energy into electricity.
- Solar cells are predominantly made from silicon – a semiconductor – the same type of material used to make computer chips.
- When these materials absorb solar energy (photons), tiny electrically charged particles called electrons are caused to move through them.

Slide 15: ***Photovoltaic Panels: Converting Solar Energy (light) into Electricity***

- PV panels consist of semiconductors.
- Each cell consists of two types of semiconductor layers, one positive and one negative.
- When light shines on the semiconductor, the electric field across the junction between these two layers causes an electric current to flow.
- The p-type tends to get rid of the electrons.
- The n-type tries to collect them.
- Light gives the energy for electrons to move between the two layers, and this flow generates electricity.
- The greater the intensity of light, the greater the flow of electricity.

Slide 16: ***Small-scale photovoltaic Systems***

- Small PV systems can generate electricity for your household and business, but a DC (Direct Current) to AC (Alternative Current) converter will be needed.
- This solar electricity can power all electricity appliances in the house (e.g. computer, geyser, fridge, freezer, washing machine, stove, lights.)
- If the PV system produces more electricity than is currently needed:
    - Batteries can store PV electricity for times when sun is not shining
    - The PV system can feed PV electricity back into the grid (allowed in the Western Cape, conditions to be clarified)
- Independent PV panels can also be used to retrofit your existing geyser (only the geysers heating element has to be exchanged to work on AC and DC, no converter needed).

- At a photovoltaic power station, solar energy (light) is converted into electricity.

Benefits:

- Using solar energy from the sun does not cause pollution.
- Solar energy is a renewable resource, so it will never run out.
- Fossil fuels are conserved, preventing climate change.
- The energy of the sun is free and it can be used whenever the sun is shining, from your back garden, right up into space.

- PV panels generate high-value energy, namely electricity

Challenges:

- The biggest challenge for photovoltaic power stations seems to be to store energy for when the sun is not shining.

Slide 17: *PV Power Plants in South Africa*

Cost of energy-generation technologies

- The best measure to compare energy-generation technologies is the electricity generation costs (ct/kWh) over the lifetime of a plant.
- In South Africa the costs of renewable solutions have been decreasing rapidly, especially of PV.
- Because of the free-energy carrier, the sun's rays, these costs are highly predictable in comparison to e.g. coal-fired power plants, where you have to take uncertainties in future fuel prices into account.
- PV today is significantly cheaper than nuclear, even leaving all additional costs of nuclear (waste treatment, transport, etc.) aside.
- Thus, the electricity costs from renewable energy are much more predictable than from fossil or nuclear energy.
- Research by the CSIR (Council for Scientific and Industrial Research) also shows that residential-sized photovoltaic systems are already a cost-competitive alternative to other new-built options, coming in at an estimated 81 cents a kilowatt hour (kWh) versus 80 cents at Medupi or Kusile. This solar power cost includes financing at an interest rate of 9% (CSIR, 2015).