CENTRE FOR RENEWABLE & SUSTAINABLE ENERGY STUDIES

Electricity

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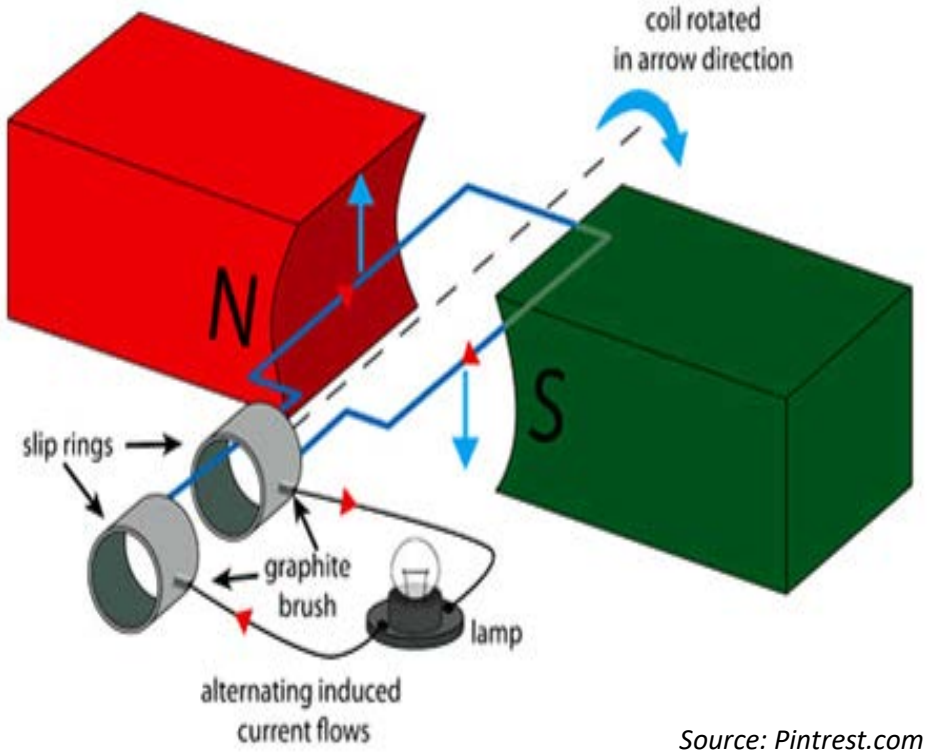
science & technology Department: Science and Technology REPUBLIC OF SOUTH AFRICA

NRF National Research Foundation

Eskom

Generating Electricity

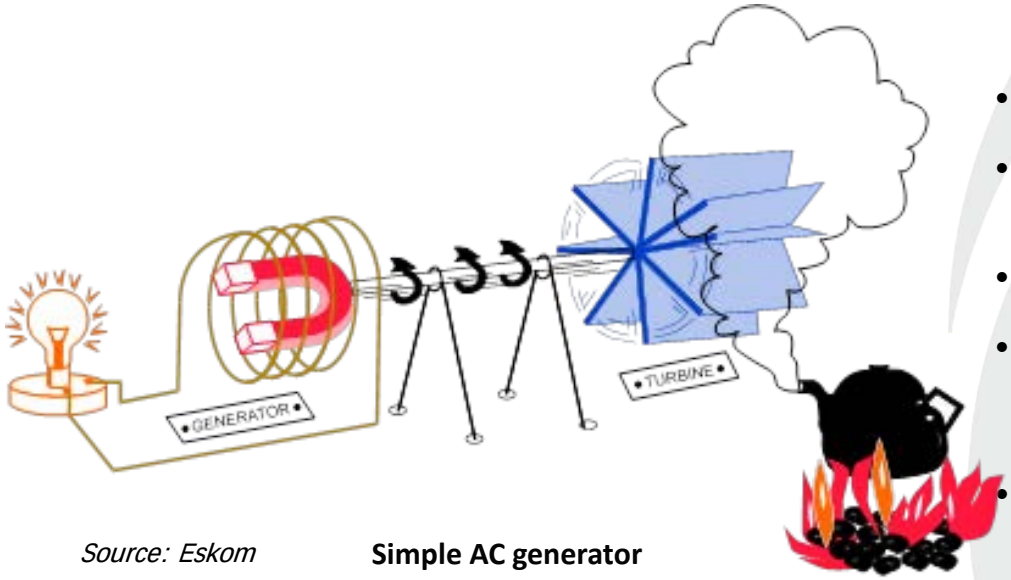


Source: Pintrest.com

Simple AC generator

- **Power stations** convert fuels into **electricity.**
- **Coal and gas** are burned to heat water and turn it into steam.
- The **steam**, at a very **high pressure**, is then used to spin a **turbine**.
- The **spinning turbine** causes large magnets to turn within **copper wire coils** - this is called the generator.
- In 1831 Michael Faraday discovered that if **magnets** and a **conductor** (e.g. a piece of copper wire) move relative to one another, **electricity** can be generated.
- **Faraday** found that the mechanical energy used to move a magnet inside a wire loop (coil) could be converted into electrical energy, flowing through the wire.
- Faraday's discovery could be summarised as the **flow of electrons** when a wire loop or coil rotates in a magnetic field.

Generating Electricity

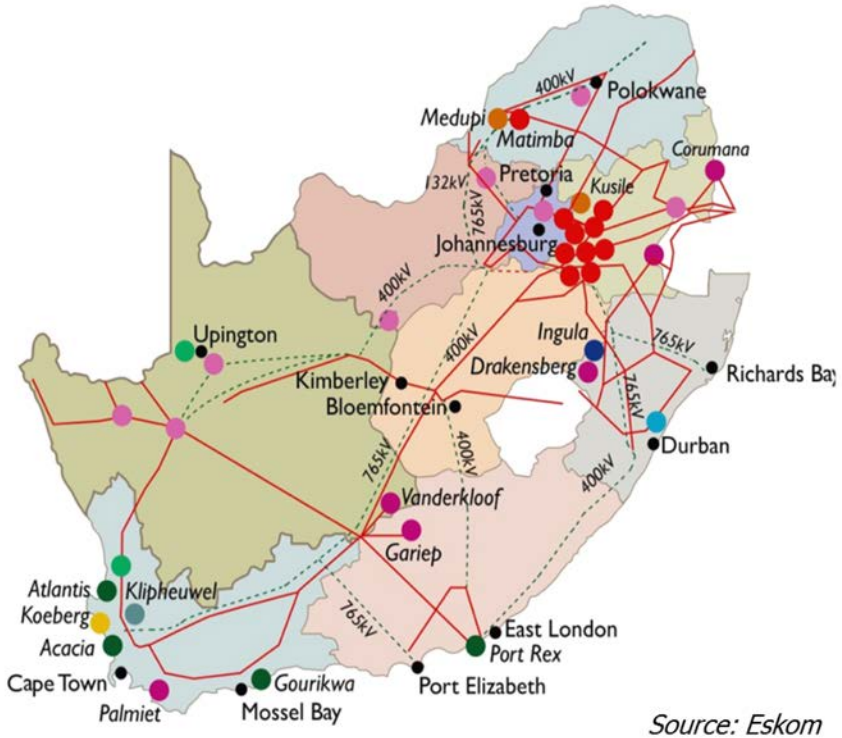


Source: Eskom

Simple AC generator

- A generator converts **mechanical energy** into **electrical energy**. That is when a wire loop or coil rotates in a **magnetic field**.
- A generator consists of a **coil, magnets** and **split rings**.
- The magnets can be **permanent magnets** or **electromagnets** which produce a magnetic field.
- The ends of the coil wires are connected to the split rings.
- The electric current flows from the coil to the **external circuit** using brushes which come into contact with the split rings.
- It is this discovery which has led to the development of modern **power plants**, providing a constant and reliable supply of large quantities of electricity to consumers.

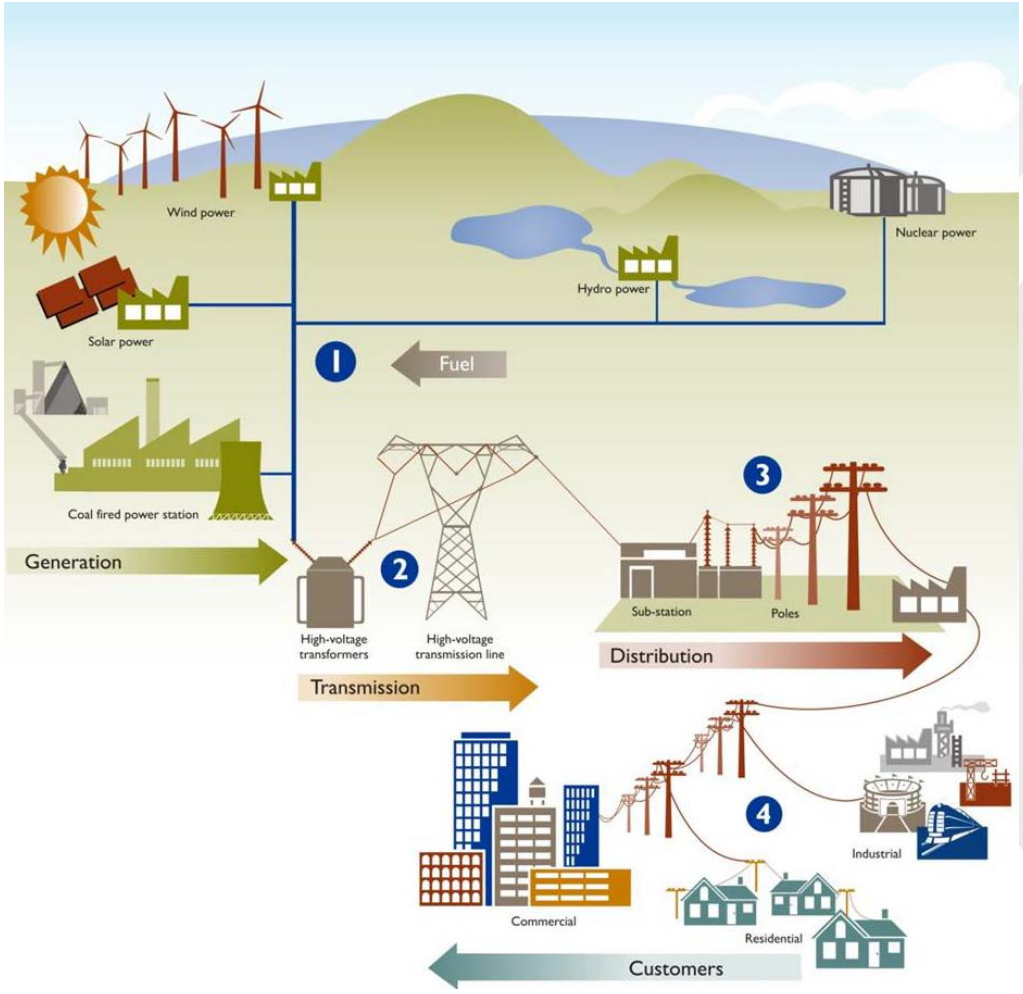
South Africa's Electricity Supply: Power Grid



- Future hydroelectric power station
- Future thermal power station
- Hydropower Station
- Interconnection substation
- Future renewables
- Renewables
- Thermal power station
- Nuclear power station
- Future gas station
- Gas station
- Town/City
- Possible future grid system
- Existing grid system

- **Eskom** is a utility company which generates and distributes electricity. It transmits electricity throughout South Africa utilizing a **national transmission system**, from where it is distributed to the end users.
- Eskom also delivers bulk supplies to approximately 180 **municipal distributors**.
- '**Transmission**' means 'to send from one place to another'. **Transmission lines** link power stations all over South Africa.
- **Pylons** support transmission lines.
- Transmission lines are manufactured predominantly from **aluminium and copper**, with **steel wire** for structured integrity.
- The network of transmission lines is called the **national grid**.
- Eskom also imports electricity from neighbouring countries such as Mozambique and exports to neighbouring countries such as Namibia and Botswana.

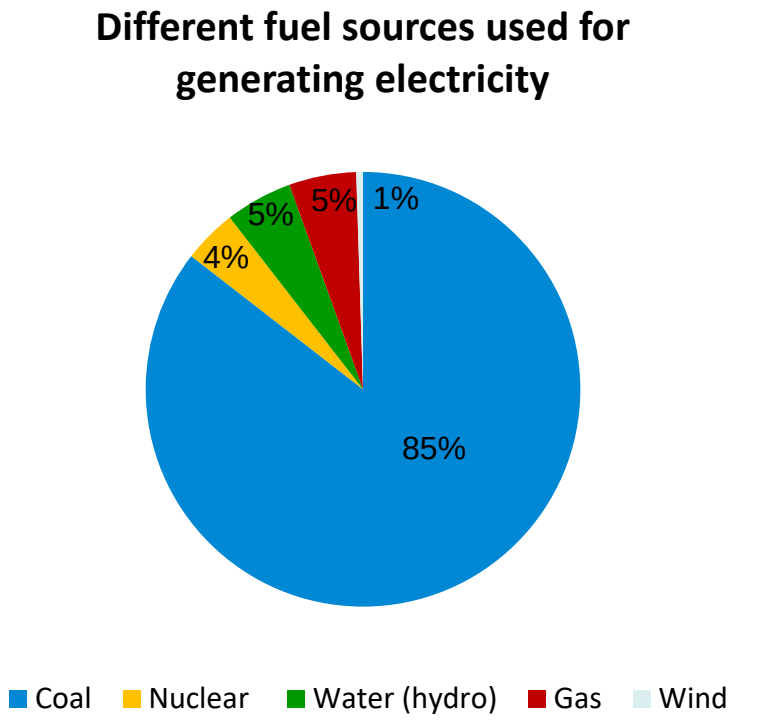
South Africa's Electricity Supply



Source: Eskom

- Electricity is produced from a variety of sources. i.e. coal, gas, nuclear, wind, solar, hydropower, biomass etc.
- The electricity produced is at **high voltages** (22kV) this voltage is then stepped up using **step-up transformers** for transmission up to 765kV.
- The electricity is then transmitted at high voltages using transmission lines to the **transmission substations**.
- Eskom uses transmission lines ranging across 132kV, 275kV, 400kV and 765kV
- The high voltages are stepped down at distribution sub-stations using **electric transformers** to lower voltages.
- These lowered voltages are then fed to the **distribution sub-stations**.
- The transformers at the distribution sub-stations also step down the voltages.
- Electricity is then distributed to consumers using the 22kV/ 11kV lines typically seen on wooden poles across the country.
- At a household, the voltage from the outlet/ plug will be ready for use at **240 Volts**.

South Africa's Electricity Supply

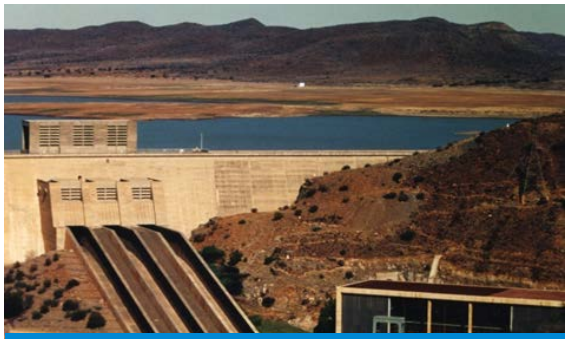


Source: Eskom

- **Coal, oil, gas** and **nuclear fuels** can be used for heating water, converting it into steam at **high temperatures** and under **high pressure**. This is done in **boilers or reactors**.
- The **steam**, which is usually heated up to temperatures of between **500 °C** and **535 °C**, is released to turn a large turbine that is connected to a generator to generate electricity.
- In this way, the energy in the fuel is converted into **electrical energy**.
- Alternatively, **gas turbines** are used to generate electricity. Gas or liquid fuels (diesel in the case of Eskom) are used in an engine very similar to an aircraft jet engine to drive an electric generator.
- In SA, Eskom relies on **coal-fired power plants** to produce approximately **85%** of its electricity.
- Eskom uses over **1 192 million tons of coal** per year.
- In 2014/2015 Eskom's coal-fired power plants produced 223.4 million tons of CO_2, had a nett power-generating capacity of **42 090 MW** (megawatt), and sold **226 300 GWh** (gigawatt-hour) of electricity.

Source:http://www.eskom.co.za/IR2015/Documents/Eskom_fact_sheets 2015.pdf

South Africa's Electricity Supply: Some Power Stations



Gariep Dam

Ankerling Gas Station

Ingula Pump Storage

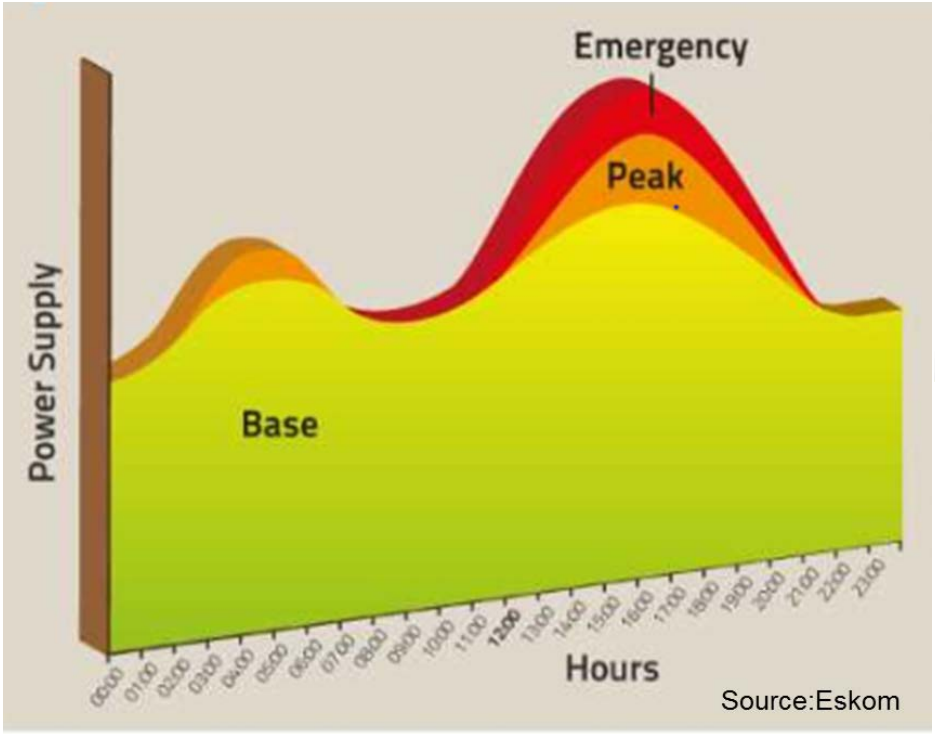
Medupi Coal Fired Station

Sere Wind Farm

Koeberg Nuclear Power Plant

Source: Eskom

Supply vs Demand: Electricity Demand Patterns



- Much of the electricity and electronic equipment we use depends on the **voltage** and **frequency** remaining accurate and **constant**.
- The instantaneous amount of electricity being **fed into the grid** (i.e. the electricity being generated) must always match what consumers are using from the grid.
- This **varies** not only from day to day, but from **minute to minute.**
- As the **demand** increases, more stations must be brought **online.**
- The pattern of the **daily demand** can be predicted fairly accurately, unless something unexpected happens, such as a **sudden deterioration in the weather** when people use more heating and drying appliances.
- The first peak period in a day usually starts at about 06:00 in the morning and lasts until about 10:00.
- The **main peak period** is normally from about **17:00** until **21:00.**

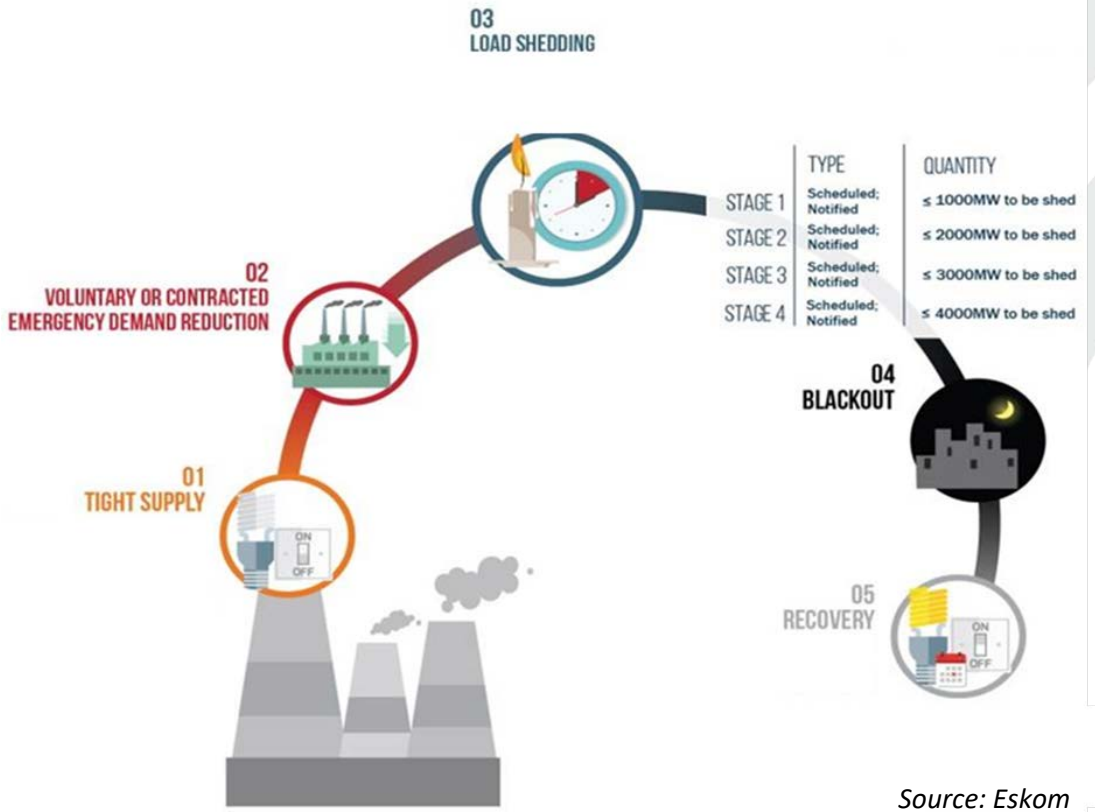
Supply vs Demand: The Energy Balance Problem

- Electricity supply should be **consistent and reliable**.
- Electricity has to be generated as needed since batteries are not capable of storing enormous quantities of generated electricity to use at a later stage.
- There is no realistic way yet to store large quantities of electricity required for distribution to users, besides **large pump-storage schemes** such as those found at Palmiet, Drakensberg and Ingula.

To supply electricity to a 220 W computer used 365 days per year, 938 kg coal is needed – that is almost one ton or a whole bakkie load!

needs

Supply vs Demand: Load Shedding



Source: Eskom

What causes load shedding?

- An **imbalance in supply and demand**, specifically when the demand is more than the supply. This is usually caused by failure on some generation units.
- Normally there are power stations that run 24 hours a day (**base stations**).
- During **peak periods** (in the morning and late afternoons), the peak up stations are put online to match the demand. When this demand cannot be met, the power utility is **forced to shed load** so that the grid doesn't collapse.
- If a grid collapse did occur, it can take up to a **month** to re-energise the country.

Renewable Energy Sources: Alternative to Fossil Fuels

There are many other methods by which electricity can be generated, for example, by harnessing solar and wind energy. The main renewable resources used today are:

Solar power:

There are two main conversion techniques of turning energy from the sun into electrical energy:

I. **Photovoltaic (PV)** converts direct sunlight into electricity

II. **Concentrated Solar Power (CSP)** uses the sun's rays by concentrating them into one point to produce very high temperatures to produce steam.

Wind:

Moving wind drive wind turbines to produce electricity.

Renewable Energy Sources: Alternative to Fossil Fuels

Hydro electricity (water):

There are two main types of electricity generation that use water:

I. **Hydroelectric power**, extraction of energy from moving water streams. Here a hydropower station is placed near a running river stream and a hydro-electric turbine is used to convert the energy from the moving water to electricity.

II. **Pumped storage power**: the power plant is placed between two dams, one on a higher level than the other. Electricity is generated by extracting energy from moving water, from the upper-level dam to the lower-level dam (generation mode). When there is less demand for power, water is pumped back up to the upper-level dam from the lower-level dam. These dams are used as electrical storage systems.

Ocean energy:

- Tidal, wave and ocean current energy
- Using **Wave Energy Converters** (WEC), tidal energy, wave energy and ocean currents are converted into electrical energy.

Renewable Energy Sources: Alternative to Fossil Fuels

Geothermal energy:

- This uses energy stored in the earth crust in the form of the molten rock, where heat is extracted to produce **steam**, thus producing electricity.

Biomass:

Many different processes can be used to produce electricity, including:

I. **Anaerobic digestion**, this is where microorganisms are used to break down organic material into combustible gas (biogas (CO_2 and CH_4)) in the absence of oxygen to generate electricity.

II. **Combustion**, direct burning of organic material to produce steam and generate electricity.

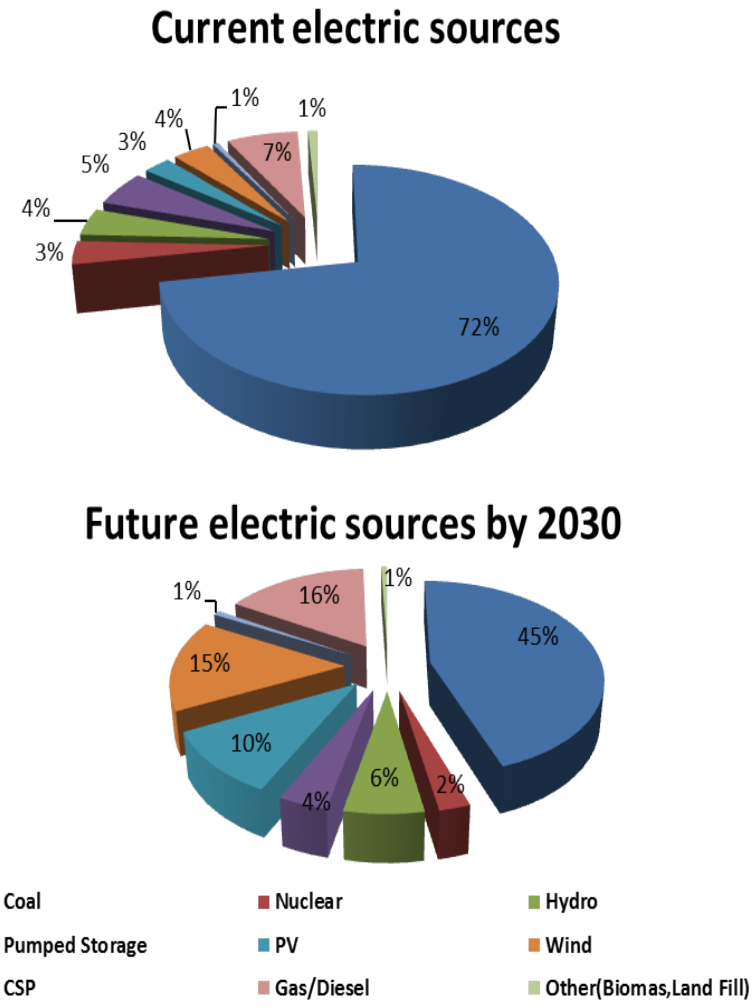
Renewable vs Non-Renewable: Comparison of Energy Technologies (2016)

- At this point, we are still making use of more non-renewable fuel sources than renewable fuel sources.
- This is due to **SA's cheaply available electricity environment** (based on coal) and the capital costs of erecting renewable energy plants.
- However, this situation is changing.
- Electricity costs are **rising yearly** and will continue to do so.
- **Mining costs** of coal, our main source of energy, are **rising**.
- The accompanying **environmental impact** of burning fossil fuels is **escalating**.
- At the same time, the research and development of **renewable energy technologies** are becoming better and **cheaper**.
- The demand for renewables is becoming bigger.
- Subsequently, it is becoming **cheaper to install** renewable energy.
- This means that **renewable energy** is becoming a viable option for generating electricity as an **alternative to non-renewables.**

Renewable vs Non-Renewable: Comparison of Energy Technologies (2016)

	Non-renewable			Renewable				
	Coal Pulverized coal without/with flue gas desulphurization	**Nuclear**	**Gas Turbines** Open cycle (OC)/ Combined cycle (CC)	**Wind** Grid connected with no storage	**Solar PV (c-Si)** Grid connected with no storage (Ground latitudinal tilt)	**Concentrated Solar Power (CSP)** With various storage time	**Biomass** Forestry residue (FR)/ Municipal Solid Waste (MSW)	**Hydro** Typically used for energy storage, included for completeness only
Installation cost Rand per MW	High	Very high	High	High but declining	High but declining	High	High	Low when excluding dam construction
Power Reliability (Availability/Capacity factor)	92% (85%)	92 – 95% (High)	89% (10 – 50%)	94 – 97% (22 – 46%)	99% (19%-21%)	95% (26 – 46%)	90% (85%)	High (10 – 50%)
CO_2 emissions	High	Low	high	Low	Low	Low	High(But Carbon neutral)	Medium (dams release methane)
Water usage	High	Very high (Sea water)	Low	None	Low (for washing)	Low	High	For storage, same water is pumped back to be reused during peak times.
Operating & maintenance costs Fixed (Variable)	High	High	High	Low	Low	Medium	Low	Low
Fuel cost estimates	High	High	High	N/A	N/A	N/A	Low	Note that water needs to be pumped back up, thus there are some electricity costs.
Base load / Peak power	Base	Base	Peak	Intermittent	Intermittent	Base (If the storage is good)	Base	Peak in SA

South Africa's Future Electricity Supply



Source: www.energy.gov.za/IRP

- The Department of Energy initiated the **Integrated Resource Plan** (IRP) for electricity in 2010.
- The IRP sets out the **new build plans** for South Africa's future diverse electricity supply from 2010 to 2030.
- It is a **dynamic plan** which investigates various scenarios and outcomes, and is constantly being updated.
- It sets the groundwork for the **REIPPPP**, the Renewable Energy Independent Power Producer Procurement Program.

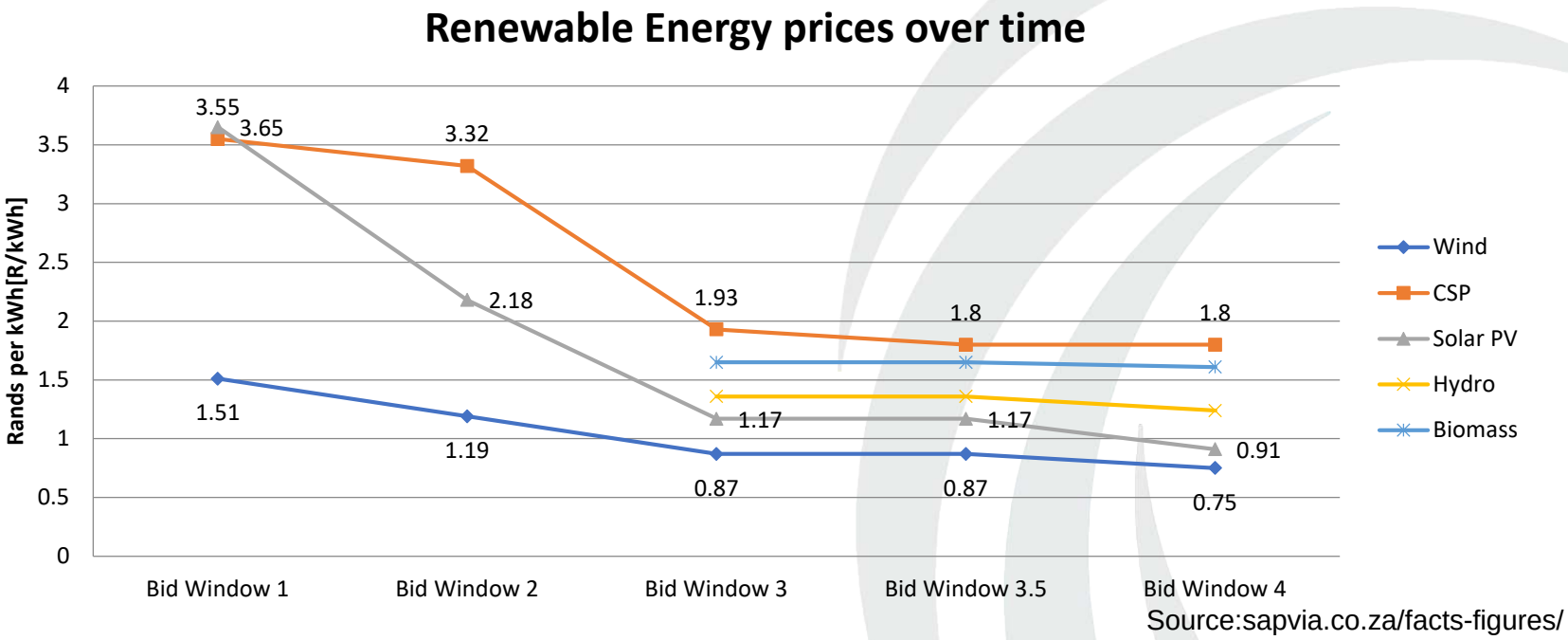
REIPPPP: Renewable Energy Independent Power Producer Procurement Program

- Decisions will have to be made as to whether to invest in renewable energy systems or to carry on burning fossil fuels and paying the environmental cost that is linked to releasing more and more CO_2 into the atmosphere.
- The **National Energy Regulator (NERSA)** is a regulatory authority whose mandate it is to regulate the electricity, piped-gas and petroleum pipelines industries in terms of the **Electricity Regulation Act of 2006**.
- The Renewable Energy **Independent Power Producer (IPP) Bid Programme** and the procurement of an IPP for new generation capacity were gazetted by the **Department of Energy (DoE)** in May 2011 (*Eskom, 2015*).
- The National Development Plan calls for the procurement of "at least 20 000 MW of renewable electricity by 2030" and the decommissioning of 11 000 MW of ageing coal-fired power station.
- In the 2014 report on the **South African IPP Procurement Programme**, Anton Eberhard, member of the National Planning Commission, indicated that an investment of 3,922 MW renewable energy generating capacity has been secured in the first three bidding rounds and it is judged to be highly successful by the programme stakeholders (*Eberhard, 2014*).

Bid Submission	Megawatts Allocated	Year started	Number of Projects
First bidding round 1	1436.32 MW	2011	28
Second bidding round 2	1090.96 MW	2012	19
Third bidding round 3	1656 MW	2013	23
Fourth bidding round 4	1084.2 MW	2015	13
Fifth bidding round	~1800 MW	To be launched	

Source: Eskom

REIPPPP vs Recently Built Coal-fired Power Stations

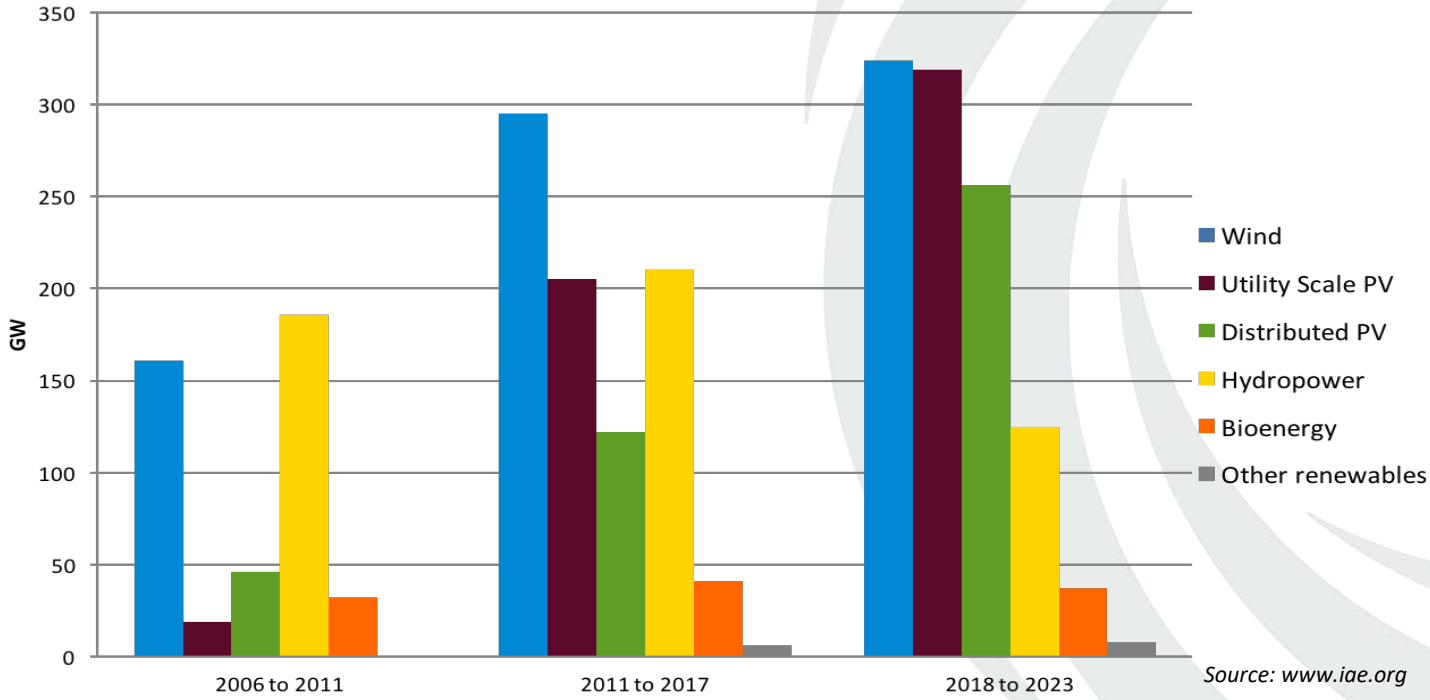


Source:sapvia.co.za/facts-figures/

- There has been a significant change in the electricity prices from renewable sources since the inception of the IPP process.
- In 2011, when the first bidding round started, the **price** per kWh was **very high**.
- As the technologies have advanced and improved, the **prices** have **reduced significantly**.
- The new coal fired power stations Kusile and Medupi were generating at R1.10c and R1.20c respectively in 2016.

Renewable Energy Targets: European Union

- The EU is working to **reduce** the effects of **climate change** and establish a common energy policy.
- By 2020, renewable energy should account for **20%** of the EU's final energy consumption, compared to 8.5% in 2005.
- The latest figures available show that the share of renewables in energy consumption in the EU stood at 16% in 2014. (*Eurostat news release Feb 2016*)



References

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Slide 11: https://www.pexels.com/photo/abstract-beach-bright-clouds (Sun), www.pexels.com/photo/close-up-photo-of-coconut-tree (Wind power)

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Slide 14:

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Slide 16: *: www.energy.gov.za/IRP*

Slide 17: Eskom

Slide 18:

Slide 19: *http://www.energy.eu/#renewable*