C19 Practical Electricity

Learning objectives

(a) describe the use of the heating effect of electricity in appliances such as electric kettles, ovens and heaters

(b) recall and apply the relationships $P = VI$ and $E = VIt$ to new situations or to solve related problems

(c) calculate the cost of using electrical appliances where the energy unit is the kW h

(d) compare the use of non-renewable and renewable energy sources such as fossil fuels, nuclear energy, solar energy, wind energy and hydroelectric generation to generate electricity in terms of energy conversion efficiency, cost per kW h produced and environmental impact

(e) state the hazards of using electricity in the following situations:
  (i) damaged insulation
  (ii) overheating of cables
  (iii) damp conditions

(f) explain the use of fuses and circuit breakers in electrical circuits and of fuse ratings

(g) explain the need for earthing metal cases and for double insulation

(h) state the meaning of the terms *live, neutral* and *earth*

(i) describe the wiring in a mains plug

(j) explain why switches, fuses, and circuit breakers are wired into the live conductor

(a) Heating effect of electricity

By Conservation Of Energy

- Electrical energy → Thermal energy (kettles, ovens and heaters)
- Electrical energy →Thermal energy of filament → light (filament glows)

(b) Calculating amount of electrical energy used

Recall:	V =	I =
Combine the equations	W =	
Substitute V = IR Substitute I = V/R		
Power = Rate at which work is done (amount of electrical energy used per second) Unit: J/s or Watt (W)		
P =	P =	P =

Joule and kilowatt-hour

Calculate the amount of work done (in Joules) by a 1000 W appliance in 1.0 hour

W = P × **t** = 1000 W × 1 hour × 60 min × 60 s = 3600000 J

A simpler unit, the **kilowatt-hour** is used to replace Joules

W = P × **t** = 1.0 kW × 1.0 hour = 1.0 kWh

Therefore 1.0 kWh is equivalent to 3600000 J

Question 1

A 1.5 kW electrical heater is used to heat a large container of water for 2.0 hours. Calculate the amount of electrical energy used by the heater in (a) J, (b) kWh.

(c) Cost of electricity = Energy (kWh) x unit cost

Source: Energy Market Authority (EMA)

Question 2

If Singapore Power charges 26 cents for each kWh of electrical energy used, calculate the total cost of using a 3.0 kW electrical kettle for 20 minutes and a 100 W filament bulb for 5.0 hours.

Question 3

(a) A 240 V mains power supply delivers a current of 9.0 A through an air-conditioner. Find the power supplied in watts.

(b) An air-conditioner is used for 1.5 hours each day. Using the answer in (a), given that the electricity tariff is $0.26 per kWh, calculate the cost of using the air-conditioner in a month (30 days).

Question 4

An electric iron with a heating element of resistance 60 Ω is connected to the 240 V mains. Calculate

(a) the electrical power produced in the heating element, and

(b) the amount of electrical energy consumed when operating the iron for 20 minutes.

Question 5

A filament lamp, rated as 60 W, 240 V, is connected to a 240 V power supply. Find

(a) the current flowing through the lamp,

(b) the resistance of the filament, and

(c) the energy produced by the lamp when it is switched on for 8 hours.

(d) Dangers of electricity

(1) **Damaged insulation**

a. Insulating materials become ___________ with time and use.

b. Bending and twisting of electrical cables may cause the electrical insulation to crack and break, thus ___________ the conducting wires inside.

c. An ___________ live wire can cause severe electric shock (high current and voltage) to the user when touched, leading to serious injuries or even death.

(2) **Overheating of cables**

❖ _______________ of cables occurs when an unusually __________ current flows through the conducting wires.

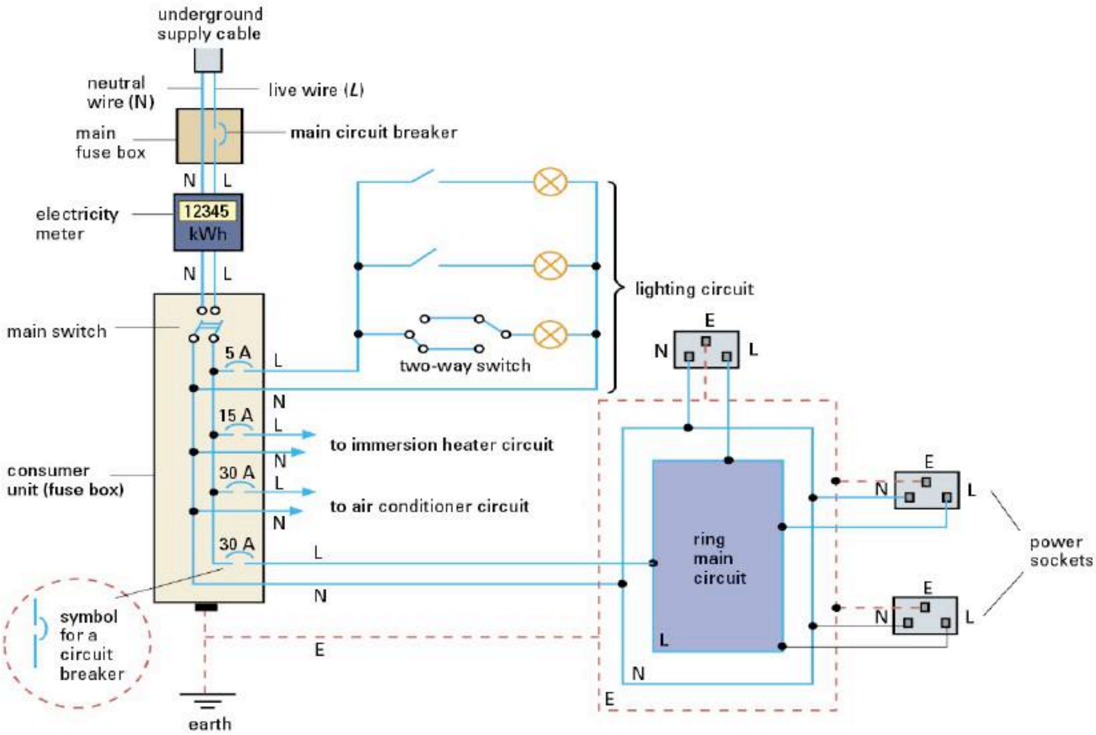
❖ A ____________wire has a higher resistance compared to a thick wire. Therefore, it will produce more ____________________ that will damage the insulation and may cause a fire.

(3) **Damp conditions**

d. For example, if a hair dryer connected to the main power falls into a bathtub while a person is bathing, the person may get electrocuted as water is an electrical conductor.

e. The water provides a ____________________________ for a large current to flow.

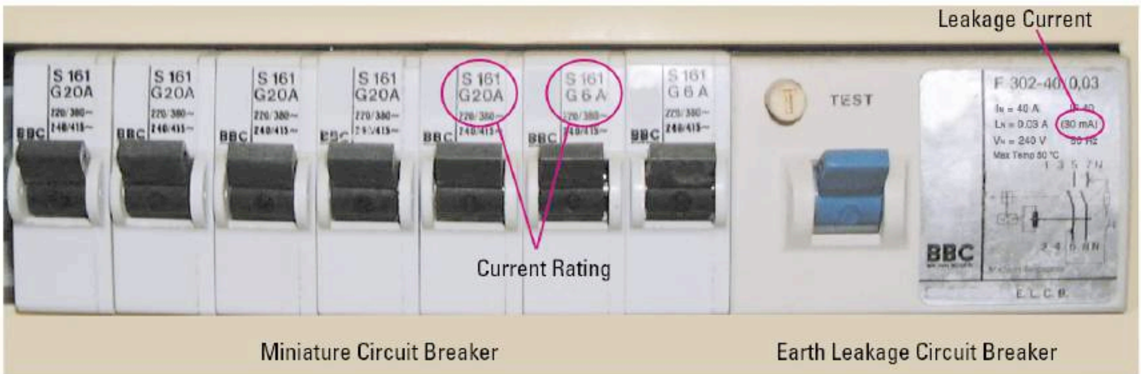
Household wiring



Electrical supply to households (240 V ac 50 Hz)

(e) Safety features

(1) Consumer unit circuit breakers



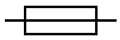
These are safety devices that can ________________ the electrical supply **when there is ____________ current** in the circuit.

- ❖ Two circuit breakers that can be found near the front door of a house:
  (a) The Miniature Circuit Breaker (MCB)
  (b) The Earth Leakage Circuit Breaker (ELCB – no longer in use) or the Residual Current Detector (RCD)

- ❖ The MCB prevents excessive current flow through the circuit by tripping or breaking it.
- ❖ The RCD detects small current leakages from the live wire to the earth wire. When this happens, the current in the live wire will be greater than the neutral wire, causing the RCD to 'trip'.

(2) Fuses

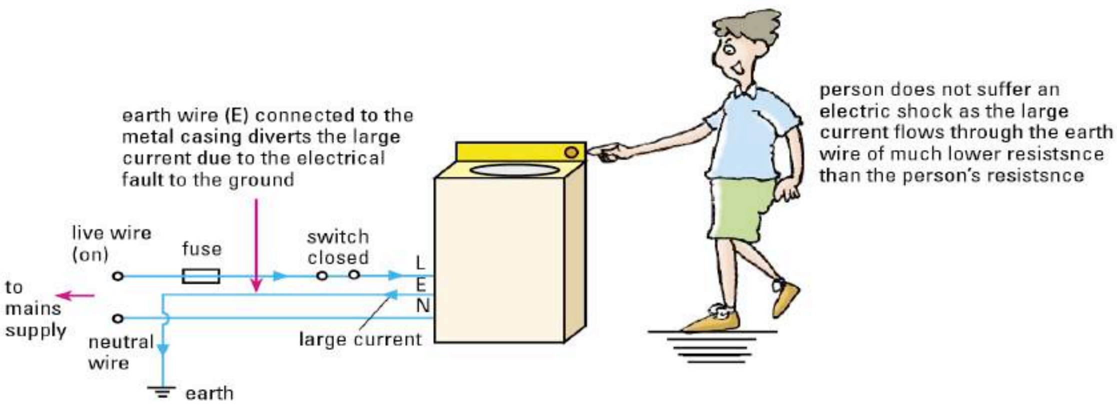
- A fuse is a safety device included in an electrical circuit to prevent excessive current flow.
- It consists of a short thin piece of wire, which becomes hot and melts when the current flowing through it is greater than its rated value.
- Fuses should have a current rating just slightly **higher** than the current an electrical appliance will use. For example a 5 A fuse is used for a lighting circuit that uses 4 A.
- A fuse **should be connected to the live wire** so that the appliance will not remain **live** after the fuse has melted due to a current surge.
- Before you change a fuse, always switch off the mains power supply.

Symbol for a fuse 

Question 6

A hot water heater is rated 2880 W, 240 V. Calculate the operating current and suggest a suitable rating for a fuse to protect the heater from overheating.

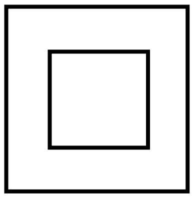
(f) Earthing



- **The earth wire (green and yellow) is a low-resistance wire and is usually connected to the metal casing of the appliance.**
- **Earthing** prevents users from getting an **electric shock** if the live wire is not properly connected and touches the metal casing of the appliance.

(g) Double insulation

- This is a safety feature in an electrical appliance that can **replace** the earth wire.
- Devices that have double insulation normally use a **2-pin** plug as only live and neutral wires are required.
- The inner layer (functional insulation) is made of a material that is both an electrical and thermal insulator.
- The outer layer (protective insulation) normally forms part of the case of the appliance.



h. Live, Neutral and Earth wires

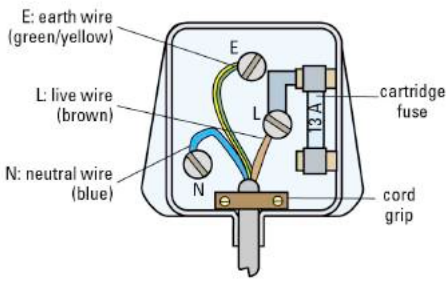
Under normal operating conditions, the voltage of each of the wires is as follows:

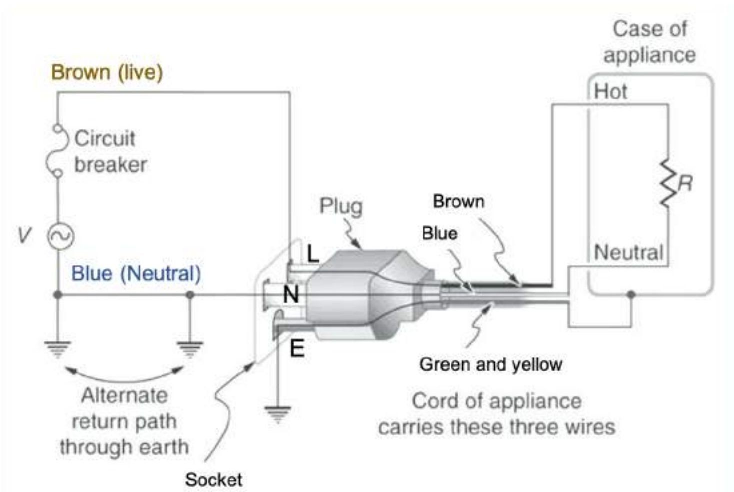
Live wire – ____________________

Neutral wire – _________________

Earth wire – __________________

i. 3 pin plug

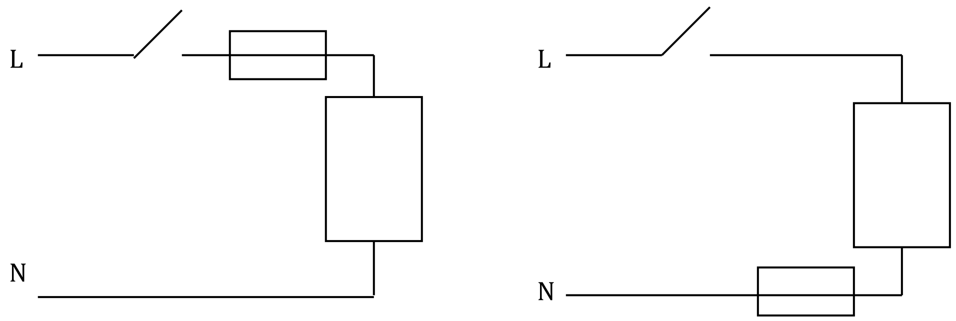




- A **fused plug** is used to connect appliances to the **mains supply** via the **power socket**.

- Inside the plug, there is a **cartridge fuse** that blows and breaks the circuit when excessive current flows in the appliance.
- Potential of live wire is always high (240 V).
- Potential of neutral wire is always zero (grounded).
- Current through live and neutral wire is always the **same** when appliance is working normally.
- The Earth wire connects the metal casing of the appliance to the ground. It **protects the user** from an electric shock when there is a short circuit.
- You will need to remember the **colours and names** of the 3 wires.

j. Position of switches, fuses and circuit breakers – always wired into the live conductor.

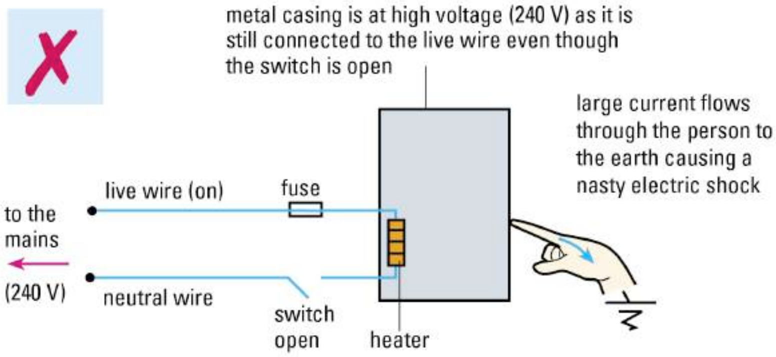


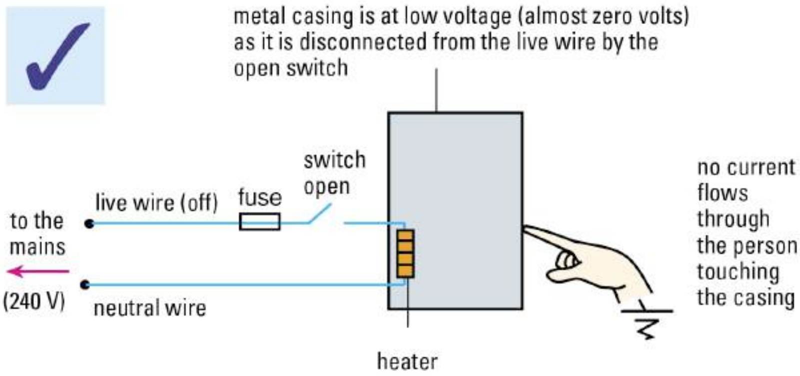
A fault in the appliance leads to a short circuit causing the current to increase. This melts the fuse and opens the circuit and the appliance stops working. (in the case of a circuit breaker, it trips and opens the circuit)

What will happen, however, if the fuse or circuit breaker is connected to the neutral wire?

If the fuse is in the neutral wire, the current stops if there is a fault in the appliance. But the appliance is still connected to the **live wire** so if you are to touch the appliance now, current will flow through your body instead. You will get an **electric shock which could be fatal**. The fuse must be in the live wire so that it **isolates the appliance from the high voltage mains** in the event of a fault.

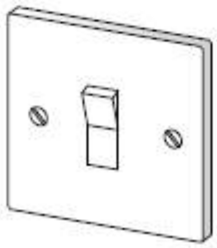
Position of the switch in a circuit





Question 7

An electrical safety expert is inspecting a laundry. The main workroom has a very hot and damp atmosphere. The expert recommends that normal domestic light switches, as shown in the Fig are replaced.



(a) Explain why this recommendation is made.

(b) Suggest how the lights should be switched on and off.

Question 8

An electric fire operating from the 240 V mains is connected to a 3-pin socket by a 3-pin plug containing a fuse. The fire (which has a metal case and a reflector) has two heating elements; one rated 1.0 kW and the other 1.5 kW, and also a 25 W lamp. The lamp is connected so that it lights when the appliance is plugged in. There are two switches, A and B on the fire. Neither element heats up unless switch A is on. When switch B is off, only the 1.0 kW element heats up; when switch B is on, both elements heat up.

(a) Draw a labelled diagram showing the connections in the fused plug, and to the heating elements and lamp. Mark clearly the positions of the two switches A and B.

(b) Calculate the current when only the lamp is on,

(c) Determine the maximum power of the appliance;

(d) Calculate the energy (in kWh) consumed when the 1.0 kW element and lamp are in used for 8.0 hours.

(e) Describe how a 'short circuit' may arise in the electric circuit and how, if a 'short circuit' occurs, the fuse in the plug prevents the continued flow of current.

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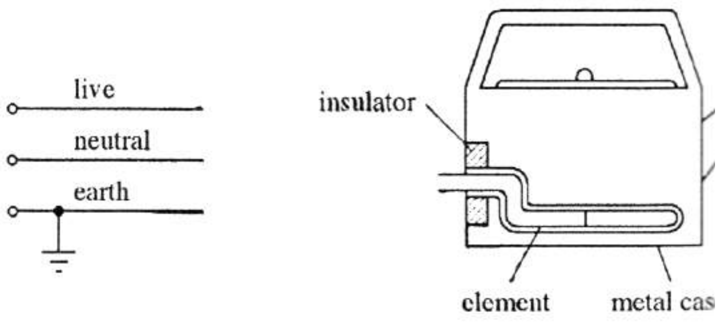
Question 9

The diagram below shows the live, neutral and earth wires of a household electricity supply. Also shown is an electric kettle.



(a) Complete the diagram to show how the kettle should be connected to the supply. Include a switch and a fuse in your drawing.

(b) Explain why the Earth pin of a three-pin plug is longer than the other two pins.

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(c) If the live or neutral wire touches the casing, the kettle stops working. Explain if this statement is correct.

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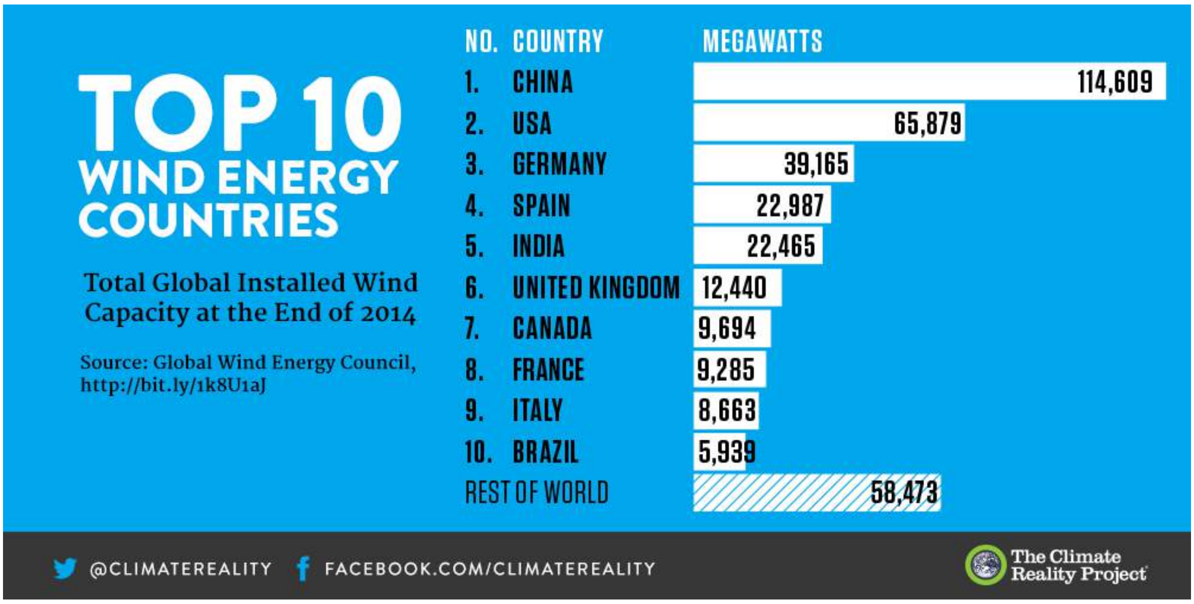
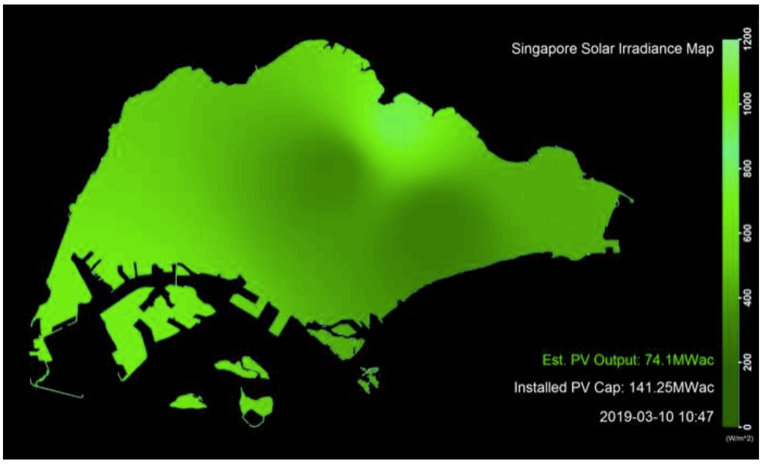
(d) Non-renewable and renewable energy sources

(h) Renewable resource – able to be replaced at a sustainable rate (wind, solar heating, biomass, geothermal, wave power, photovoltaic)
(i) Non renewable – cannot be replaced at a sustainable rate (nuclear, fossil fuel)

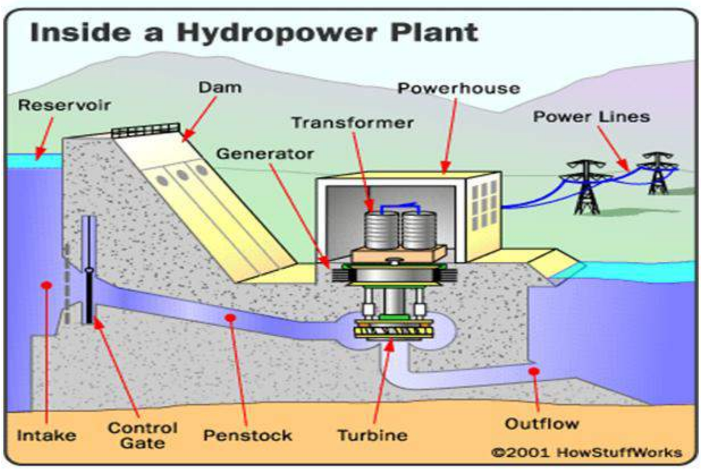


Solar energy in Singapore



This solar irradiance map shows the amount of solar power across the island which is affected by **amount of sunlight, cloud movement and shade (PV = photovoltaic)**

Hydroelectric Power Plant



Energy source	Efficiency	Cost per kWh	Environmental impact
Fossil fuel	Natural gas stations ~ 45% Higher in co-gen stations	Relatively low Fuel is relatively cheap Established technologies – power stations, transport and storage systems	Greenhouse gas emissions and global warming Chemical pollution during mining and burning (acid rain) Extraction/mining can damage the environment and be hazardous to health Leakage from oil tankers or oil pipelines can cause considerable harm to the environment
Nuclear energy	Overall efficiency not very high due to costs involved	Cost of cleaning up is massive	Dangerous and long-lasting radioactive waste products No greenhouse gases emitted during normal operation
Solar energy	Dependent on amount of sunlight, cloud cover, shade	High cost of PV cells and maintenance PV cells have a lifespan of 20 years Requires back up energy supply	Does not produce greenhouse gases Large areas needed for solar power stations
Wind energy	Dependent on amount of wind	Requires back up energy supply	Does not produce greenhouse gases Requires large land area which may affect ecosystems
Hydroelectric generation	Relatively high efficiency	Cost of transportation due to remote locations of HEP stations	Environment will be affected and the natural habitat of plants and animals may be destroyed If dam bursts it can cause considerable damage Does not produce greenhouse gases