G621: Analysis at Work – Sample Assignment B

Unit Name: Analysis at Work	**Unit Number:** G621
Assignment Title: Producing Electricity	**Assignment:** G621 Sample Assignment B
Date Set:	**Due Date:**
Assessment Objective(s): AO2(a) & AO2(b)	

Vocational Brief:

Most electricity in the UK is generated in large power stations and sent to us via the national grid and local underground cables. Some electricity is generated locally at homes and places of work and this is increasingly being encouraged in the case of renewable sources such as wind and solar power.

In this assignment you are asked to compare large-scale and small-scale electricity production from two chosen fuel or energy sources.

Task 1:

Choose two sources from which electricity is generated on both large-scale and small-scale. It will simplify the later stages of this assignment if one source is renewable and one is non-renewable.

Draw energy transfer diagrams showing the conversion of the energy from each of your chosen sources to electrical energy.

Task 2:

For each of your chosen energy sources, research large and small-scale electrical generation. Write a report describing and comparing large and small-scale production for each of your chosen energy sources.

Task 3:

3.1 For your chosen **non-renewable** fuel, research the energy (calorific) value of the fuel and the cost of the fuel. Use this information to calculate the cost per joule of the energy obtained from the fuel. Use an estimate of the efficiency of a power station or generator to calculate the fuel cost per kWh of the electricity produced.

3.2 For your chosen **renewable** energy source research the capital costs of generating electricity for a given installation and the likely annual energy output in kWh.

Use this information to obtain the fuel capital cost per kWh of the electricity produced over a ten year period. Compare your answer with typical costs of domestic electricity.

[Max marks possible for this task: 10]

Resources:

Energy values are given on the Kaye and Laby website:

- www.kayelaby.npl.co.uk/chemistry/3_11/3_11_4.html

The Nottingham energy partnership website also includes a useful table of energy value and cost data:

- http://www.nottenergy.com/energy_cost_comparison/

The BWEA website gives data on wind energy costs:

- www.bwea.com/

The Centre for Alternative Technology, Machynlleth, Powys, Mid Wales, SY20 9AZ:

- www.cat.org.uk

Electrical generation and supply companies:

- www.powergen.co.uk
- www.scottishpower.co.uk
- www.swalec.co.uk
- www.southern-electric.co.uk
- www.sweb.co.uk

Other sources:

- www.darvill.clara.net/altenerg/index.htm

Your sources may include textbooks, websites and, if possible, a visit to a power station or alternative technology centre.

Exemplar Material with Commentary – for Sample Assignment B
Unit G621: Analysis at Work (AO2)

ASSESSOR'S COMMENTARY ON MARK ALLOCATION

Commentary on mark allocation has been included throughout the work highlighted in grey boxes.

Producing Electricity

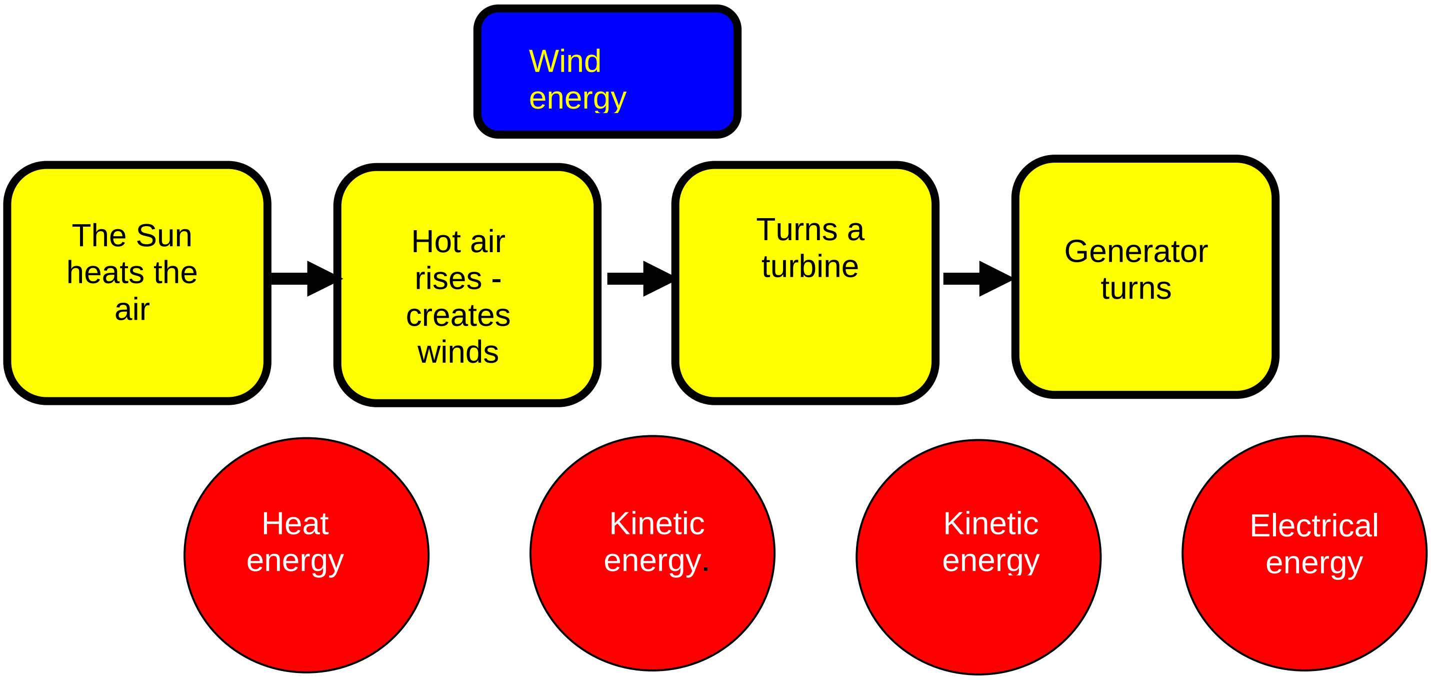
Task 1:

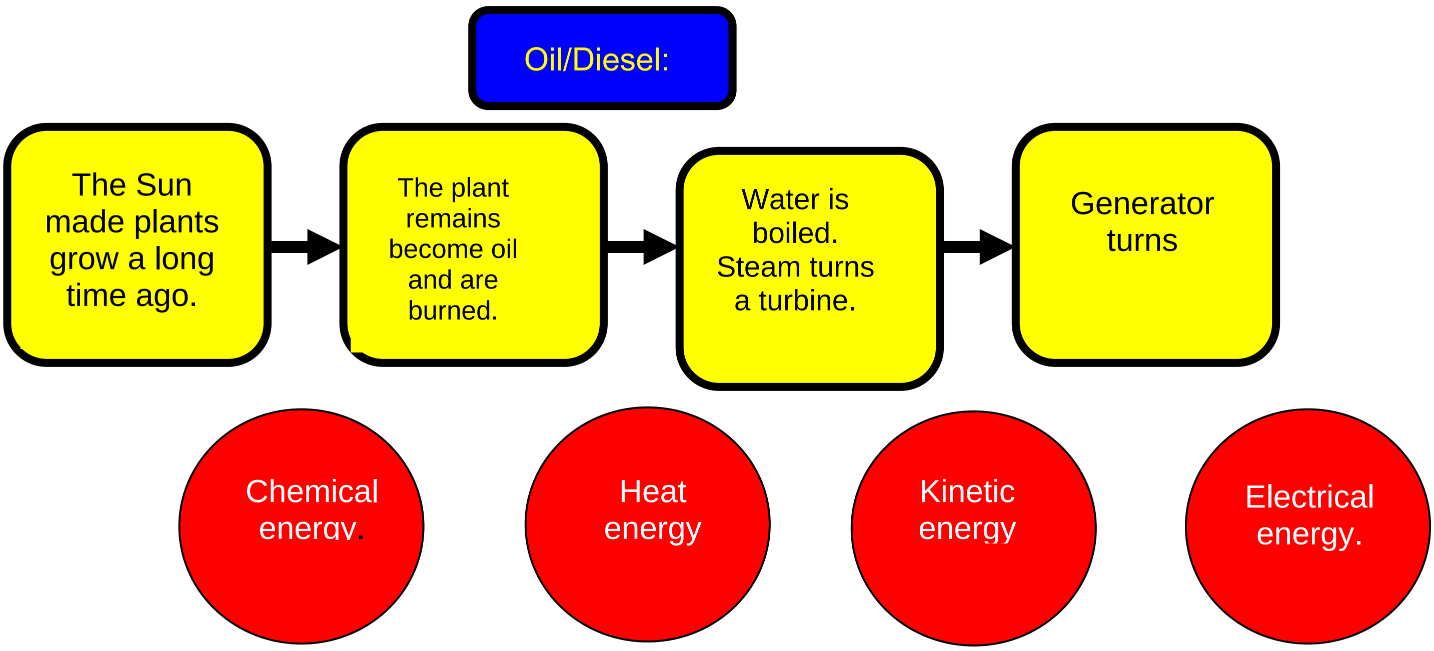
Chosen Sources:

Renewable: Wind

Non- Renewable: Diesel (Oil)

Energy Transfer diagrams:





Task 2:

2.1 Diesel/ Oil

2.11 Large-scale.

A number of oil fired power stations were built in the UK in the 1960s and 1970s. These were often constructed near oil refineries, which in turn are usually built near the coast as this was where oil was brought in by oil tankers and more recently by North Sea pipelines. Another advantage of building power stations on the coast is that seawater can be used for cooling so that the large cooling towers, commonly seen at inland power stations, are not needed.

Heavy fuel oil from storage containers is first warmed in oil heater houses and from there, pumped under pressure into the boiler combustion chambers. Water is passed through turbines in the wall of the boiler and turns into steam. The steam is passed into turbines, where it turns the rotors. This turns the electromagnetic generators.

The alternating current electricity from the generators is fed to transformers which convert into electricity at high voltage so that it can be transmitted across the country via the cables without too much heat loss.

One of the advantages of oil fired power stations compared to coal-fired stations is that very little ash is produced. Flue gases

One example of an oil-fired power station is at Grain on the River Medway in Kent. There are two 675 MW oil fired generating units.

Oil fired power stations typically have an efficiency of efficiency of up to 40% oil-fired plants.

As the world's supply of oil is gradually used up and the price has risen, oil fired power stations have become economically less viable. In common with other fossil fuels they also produce greenhouse gases. In recent years a number of British oil fired power stations have closed.

Commentary on Mark Allocation
MB2 partially achieved, but more marks might have been gained if the candidate had given more details of the generation process and slightly less background information.

The candidate included a picture of a Turbine Hall in an oil fired power station here. For the purposes of distributing this support pack, the image has been removed for copyright reasons.

2.12 Small scale.

Small diesel generators are commonly used where mains electricity is unavailable. Typical users include fisherman repairing their boats on the quayside, workmen repairing roads and as standby generators in case of power failures in critical situations such as hospitals and computer installations.

Small portable units may be carried short distances. Larger units such as those used for to power temporary traffic lights and power tools at road works are built on special trolleys or road trailers.

One such unit is the SDMO SD 6000 Te-2 Electric Start Diesel Generator 6.5 KVA Yanmar Engine, which retails for approximately £3000. It has a mass of 193 kg and is mounted on a hand cart. It can produce about 5 kW of electrical power.

Fuel consumption is 1.3 L h^{-1}

Unlike large-scale oil fired power stations, these units do not produce steam. The engines work in the same way as diesel car engines. The fuel causes explosions inside the engine cylinders. Pistons cause a crankshaft to rotate and this directly turns the electrical generator. The output voltage is normally 110 V or 230 V. The latter is normal domestic UK mains voltage. The former is often used for power tools on building sites where the possibility of cables being accidentally cut is higher than for permanent cabling.

Commentary on Mark Allocation
Very brief.
Section 2.1 partially achieves MB 2 but not MB 3 because benefits and problems have not been compared.

2.2.1 Large scale wind generation

Wind farms are a collection of a number of wind turbines. They are may located on land, typically on hilltops or open flat land where the wind is stronger. Off-shore installations are more expensive to build but have less environmental impact and are unlikely to be subject to objections.

We will consider the case of off-shore wind farms.

Piles are driven into the seabed and on these a foundation is constructed with its top above high tide level. The base is protected from erosion, at the sea floor and the top of the foundation is painted a bright colour so that ships can see it. The foundation has a platform to allow access for maintenance.

Commentary on Mark Allocation
More detail about the turbine could have been included to fully achieve MB2.

A pre-fabricated tapering steel tower is installed on the foundation. The turbine is mounted on the top of the tower. This is driven round by three blades made of fibre glass. Sensors detect the wind direction and small motors turn the turbine so that the blades face into the wind.

Undersea cables take the electricity from the individual turbines to a single transformer nearby. This converts the electricity to a high voltage (33kV) for transmission to a substation on land, typically 5 -10 miles away. From there the power is fed into the national grid.

One of this country's first offshore wind farms is at Scroby Sands, 3km off the Norfolk coast. It started working in 2004. The tower is 68m high and the blades are each 40m long. The capital cost to build the 30 turbines was £75 million. Each turbine generates 2 MW, making 60 MW for the entire installation.

2.2.2 Small-scale wind power

Small wind turbines are installed in various types of location. For example:

Remote locations, where mains power is unavailable.

"Eco-friendly" housing projects, where the installation costs are assimilated into the overall cost of construction and planning permission may only be obtained on condition that the dwellings are built in and environmentally friendly manner.

Schools, where the value of the power produced is supplemented by educational value of helping children to understand about the importance of using renewable energy.

The principle of operation of these turbines is very similar to individual turbines on wind farms, but on a smaller scale and producing less energy per unit.

For example the 5 kW wind turbine installed at Tebbutt's Farm, near Loughborough has tower a 12 m high.

The electricity produced is normally used locally, but surplus power may be fed into the grid and is paid for by the electricity companies. The price paid is relatively high as the power contributes the companies' renewable energy targets.

Commentary on Mark Allocation
Partially achieves MB 2 but not MB 3 because benefits and problems not compared.

Task 3:
3.1

Diesel fuel costs £1.10 per L (local garage)

Calorific value per unit mass = 46 MJ kg^{-1} (Kaye & Laby website)

Density 820 kg m^{-3} (SI metric website)

Calorific value per m^3

= Calorific value per unit mass x density

= 46 x 820

= 37.7×10^9 MJ m^{-3}

Calorific value per L

= Calorific value per $m^3 \div 10^3$

= $37.7 \times 10^{9-} \div 10^3$

= 37.7 MJ L^{-1}

Cost of energy in diesel fuel per MJ

= Cost per L/energy per L

= $\dfrac{110}{37.7}$ = 2.92 p MJ^{-1}

Max estimated efficiency of oil fired power stations = 40%.
Assuming (!) this figure to apply to small scale generators:

Cost of electricity per MJ = $2.92 \times \dfrac{40}{100}$ p MJ^{-1}

= 1.16 p per MJ

1 kWh = 3.6 MJ

Cost of electricity per kWh = 1.16 x 3.6

= 4.2 p kWh^{-1}

Alternative calculation based on manufacture's fuel consumption for the SDMO SD 6000
Te-2 Electric Start Diesel Generator 6.5 KVA Yanmar Engine,

Output = 5 kW of electrical power.

Fuel consumption is 1.3 L h^{-1}

In 1 hour the generator uses 1.3 L of fuel to produce 5 kW h of electrical energy.

Electrical energy produced per L

$$= \frac{5}{1.3} = 3.85 \text{ kW h L}^{-1}$$

Cost per L = £1.10

Cost of fuel per kW h of electricity produced

$$= \frac{110}{3.85} 1$$

$$= 29 \text{ p kWh}^{-1}$$

The difference between this and the figure above suggests that the efficiency of small diesel generators is considerably nearer 6% than the 40% assumed above.

E.ON currently offers electricity for sale at a cost of approx 22p per kW h for the first 900 kWh per year and 11 p per kW h thereafter. The small diesel generator is more expensive than using mains electricity

3.2

For your chosen **renewable** energy source research the capital costs of generating electricity for a given installation and the likely annual energy output in kWh. Hence obtain the fuel capital cost per kWh of the electricity produced over a ten year period. Compare you answer with typical costs of domestic electricity.

The Scroby sands wind farm cost £75 million.

The maximum output is 60 MW. However, the wind does not blow all the time. Large wind turbines usually operate 75-90% of the time, but not at full capacity. They are estimated to generate 30% of their maximum theoretical capacity,

Average output = 30% of 60 MW = 18 MW.

In 1 hour the wind farm will produce 18 000 kWh of electricity.

In 1 year the wind farm will produce 365 x 24 x 18000 kWh of electricity = 1.58×10^8 kWh of electricity.

In 10 years the wind farm will produce
$10 \times 1.58 \times 10^8$ kWh = 1.58×10^9 kWh of electricity.

Capital cost in pence per kW h

$$= \frac{75x10^6}{1.58x10^9} x100 = 4.7 \text{ p per k Wh}$$

E.ON currently offers electricity for sale at a cost of approx 22p per kW h for the first 900 kWh per year and 11 p per kW h thereafter. Even allowing for running and transmission costs the wind farm should be profitable.

The 2.5 kW turbine installed at Ladygrove Primary School in the West Midlands cost £12,000 and saves £400 per year in energy costs. This would take 3o years to recoup the capital cost even without taking interest costs into account.

Average output = 30% of 2.5 kW = 0.75 kW.

In 1 hour the wind farm will produce 0.75 kWh of electricity.

In 1 year the wind farm will produce 365 x 24 x 0.75 kWh of electricity = 657 kWh of electricity.

In 10 years the wind farm will produce
10 x 657 kWh = 6.57×10^3 kWh of electricity.

Capital cost in pence per kW h

$$= \frac{12x10^3}{6570} x100 = 182 \text{ per k Wh}$$

This small wind generator is not justifiable on economic costs alone.

References

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