Assignment Brief 2.2

Unit Name: Analysis at Work	**Unit Number:** Unit 2
Assignment Title: Producing Electricity	**Assignment Number:** 2.2
Date Set:	**Due Date:**
Assessment Objective(s): AO2 a and b	

Brief:

There is considerable debate about the relative merits of the alternative sources for generating electricity. Your task is to investigate and report on **one** method of electricity production, complete a number of calculations and evaluate electrical generation.

Task 1:

Gather information on **one** method of generating electricity, include the forms of energy transfer involved and any costs. Present your research work either in a report or through a presentation.

Task 2:

Carry out calculations based on either the data you have gathered, or provided data, to illustrate the costs of generation of electricity.

Task 3:

Carry out further research to compare and evaluate the benefits and problems of large scale and small scale electrical generation.

Max marks possible for this task: 10

Resources:

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

www.cat.org.uk

http://www.blatchingtonmill.org.uk/subjects/science/Science/KS4%20Module%205%20Revision%20list.htm

http://www.darvill.clara.net/altenerg/index.htm

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

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

Exemplar Material with Commentary
Unit 2: Analysis at Work (AO2)

Please note that for the purposes of publication of this support pack, a number of diagrams have been omitted from the following portfolio for copyright reasons. Candidates should of course include such illustrative material and provide appropriate references to sources.

Candidate Portfolio Work	Commentary on Mark Allocation
Producing Electricity from the Tide	Achieves Mark Band 3 on both strands. Achieves 4 marks out of a maximum of 5 for strand AO2a and 4 marks out of a maximum of 5 for strand AO2b.
Introduction Tidal power uses the twice daily variation in sea level caused the tides.	
The Cause of Tides Tides are caused by gravitational forces of the moon and the sun acting on the oceans. The attraction causes the surface of the oceans to be raised and lowered as the earth rotates every 24 hours and the moon rotates round the earth every 28 days. There are two tides each day. This is because the Moon makes the oceans bulge out towards it. Also, on the other side of the earth, the gravitational effect is partly shielded by the Earth and the oceans on that side bulge out away from the Moon, due to rotational forces. See diagram below (Adapted from Boyle, 1996)	The energy transfer diagram, on page 4 together with the detailed description of the tides opposite and the alternative types of tidal generation page 4 (barrage) page 5 (bulb turbine), page 6 (tidal fence) and page 7 (tidal turbine) as well as older ways of harnessing tidal power (Page 3) clearly achieve at Mark Band 3.

The height of the tides varies over a period of 28 days, according to the relative positions of the Sun and Earth. When the Sun, the Earth and the moon are all in line the tides are higher. These are called spring tides, although they happen in all four seasons. See diagram below. The height of a so-called spring tide is often about twice that of a neap tide (when the sun and moon at right anlges whn viewed from the earth)

The candidate included a diagram at this point to illustrate the generation of neap and spring tides by the relative positions of the sun and moon – this has been omitted for copyright reasons.

(Boyle 1966 in reslab.com[4])

The height of the tides also varies at different times of the year, and there are even other variations over periods of 9 years and 1 600 years due complicated gravitational relationships.[2]

Use of Tidal Energy in the Past

Use of tidal energy is not new. It was used in Britain and France from the 11th Century until the Industrial Revolution for milling grains.[4]

Eling tide mill, shown in the picture below, is the last surviving tidal mill in Britain. It is near Southampton Water. There has been a mill at the site for at least 800 years[8].

The candidate included a photograph at this point to illustrate Eling tide mill – this was taken from the website referenced above, and has been omitted for copyright reasons.

"Upstream" View of the Elingmill.

The wheel is located in the section of the buildings just to the right of the wooden hut. The entrance to the sluice can just be seen at the bottom centre of the picture.
(From Eling[8])

The diagram below (Eling [8]) shows how the water drives the wheel. The power is then used directly to grind corn.

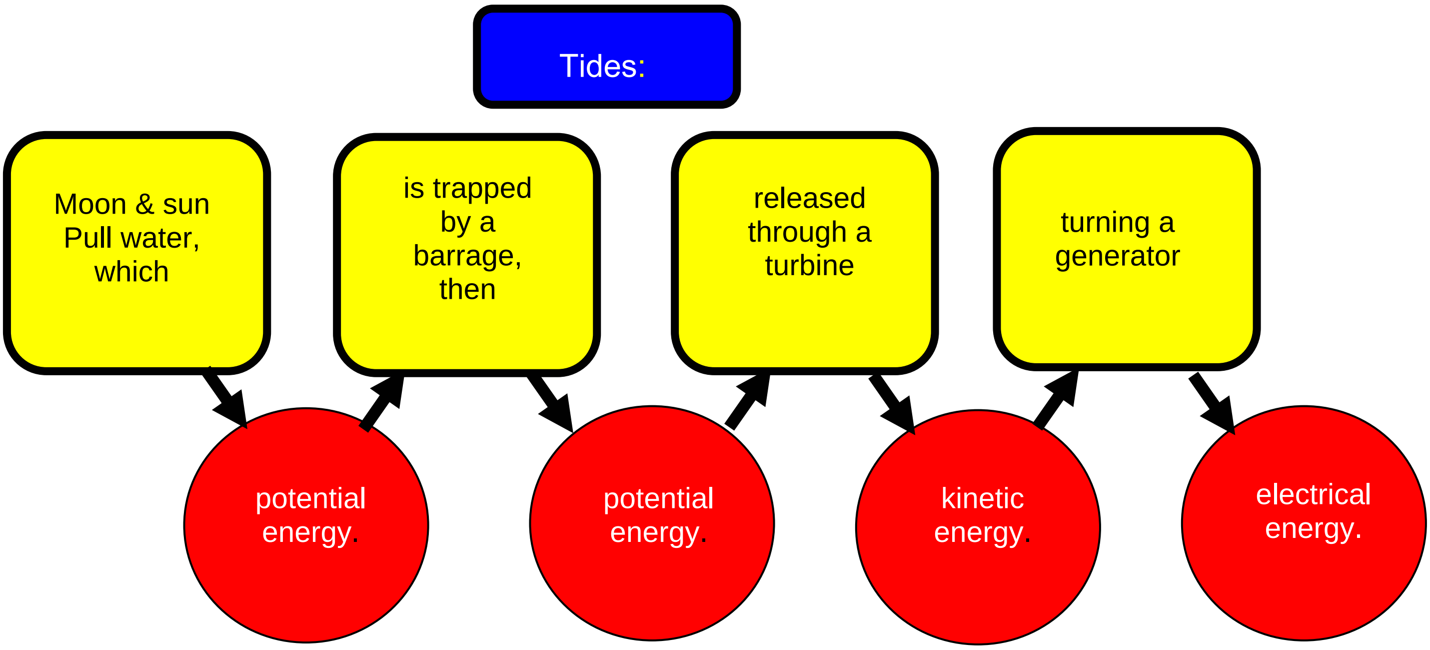
The candidate included a line diagram at this point to illustrate the working of Eling tide mill – this was taken from the website referenced above, and has been omitted for copyright reasons.

Electricity from the Tides

Nowadays we generate electricity from the tides. Tidal power stations are very similar to hydroelectric power stations, except that water is able to flow in both directions

Energy Transfer Diagram

The diagram below is an energy transfer diagram for tidal power. It is adapted from information in www.blatchintonmill.org.uk[6]



Use of Tidal Energy Today

The simplest system is called ebb generating. A dam, called a barrage, is built across an estuary. Sluice gates in the barrage open to fill the basin when the tide comes in. The water goes out through to a turbine system when the tide goes out (called an ebb tide). Two-way generation, on both the incoming (flood) and ebb tides is possible, but some engineers believe that it is better to allow as much water as possible to flow in during the ebb tide get the most power out when it is released. Some schemes even use reverse pumps to increase the amount of water in the basin.

In modern tidal power stations, the water drives a turbine instead of a water wheel. The turbine then drives a generator to make electricity.

The diagram below shows a Bulb turbine as used in La Rance (described later).

The candidate included a line diagram at this point to illustrate the working of a Bulb turbine – this was taken from the website referenced below, and has been omitted for copyright reasons. Bulb Turbine (Boyle 1966 in reslab.com[4]) The available energy is approximately proportional to the square of the tidal range.[2] It is only practical where tides are large. There are two commercial scale tidal barrages working in the world. One is in France, across the Rance estuary in Brittany it was completed in 1967[5] and can operate at 240 MW. It provides 90% of Brittany's needs[9] The dam is 330 m long, the basin is 22 km^2 and the tidal range is 8 m.	
<u>Calculation of power available:</u> Assumptions: The basin is of uniform cross-section All the water passes through the turbines every day. All this energy is converted into electricity All the water falls the full height of tide Volume of water in basin = Area x tidal range = 22 x 10^6 x 8 = 176 x 10^6 m^3 Mass of water in basin = Volume x density = 176 x 10^6 x 1000 = 1.76 x 10^{11} kg potential energy of water dropping the height of tide = 1.76 x 10^{11} x 10 x 8 = 1.41 x 10^{13} J Power if this amount of energy was converted in 12 hours Power output = potential energy lost / time = 1.41 x 10^{13} / 12 x 3600 = **330 MW** to 2 sig. figs. This suggests an efficiency of 240 x 100/330 ~ 70%.	This calculation, together with those on pages 7 and 9 satisfy the requirements for complex calculations, because they are multistage, they use the form 10^{11} etc. and at one point use a squared term, albeit a very simple one. Results are rounded to an appropriate degree of accuracy. The first part of the strand AO2b is met at **Mark Band 3.**

The photgraphs below show the La Rance barrage

The candidate included photographs at this point taken from the website referenced below. These have been omitted for copyright reasons.

La Rance Tidal Power Station
(Image from reslab.com originally from Popular Mechanics)

The other commercial scale tidal barrage is a 16 MW plant at Annapolis Royal, Nova Scotia, Canada.[4]

The height of the tide depends on the shape of the coastline. It is much bigger in long, trumpet-shaped estuaries. For example, the mean spring tidal range of is over 11 m in the Severn Estuary. There have been suggestions of building a barrage across the Severn Estuary in England but people are worried about the effect on the ecology.

Tidal fences

A variation on the tidal barrage is the tidal fence (see picture below. One advantage is that all the electrical equipment (generators and transformers) can be kept high above the water.

The candidate included a diagram at this point to illustrate a tidal fence – this was taken from the website referenced below, and has been omitted for copyright reasons.

A Tidal Fence (fujitaresearch.com[9])

The ecological effect

The biggest disadvantage of tidal power is the effect on the plants and animals. Tidal energy barrages would modify existing ecosystems. Some areas would be flooded. Sediment would be moved. Current strengths would be reduced.

Estuaries are important to fish. Barrages could act as barriers to migration and damage fish.

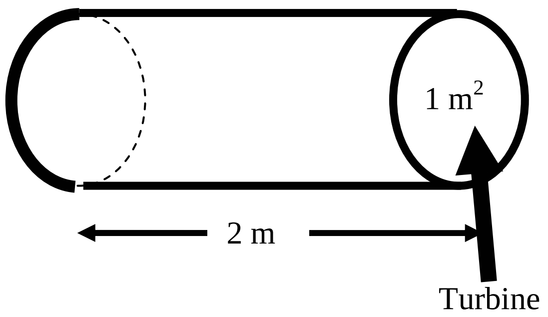
The Rance Barrage was built between two coffer dams. The water trapped between the dams stagnated but the ecosystem recovered once the barrage began operation.

Tidal Turbines

One way that has been proposed to reduce the ecological effects of tidal power stations is to use tidal turbines. These are driven directly by the current moving at 2 to 3 m s^{-1} to generate 4 to 13 kW m^{-2} (reslab[4]).

Calculation of power from a 1 m^2 cross section of water travelling at 2 m s^{-1}.

In 1 s all the water inn the cylinder shown in the diagram will pass through the turbine



Volume of water in cylinder = Area x length
= 1 x 2 = 2 m^3
Mass of water in cylinder = Volume x density
= 2 x 1000 = 2000 kg
Kinetic energy of water in cylinder = ½ m v^2
= ½ 2000 x 2^2 = 4000 J
Assuming that all this energy is converted into electricity
Power output = kinetic energy lost / time
= 4000 / 1 = 4000 W = **4 kW**

Calculation of power from a 1 m^2 cross section of water travelling at **3** m s^{-1}.

Volume of water in cylinder = Area x length
= 1 x 3 = 3 m^3
Mass of water in cylinder = Volume x density
= 3 x 1000 = 3000 kg
Kinetic energy of water in cylinder = ½ m v^2
= ½ 3000 x 3^2 = 13 500 J
Assuming that all this energy is converted into electricity
Power output = kinetic energy lost / time
= 13 500/1 =13500 W=13.5 kW

A 15kW 'proof of concept' turbine has been operated on Loch Linnhe. The Seaflow project is now under way at Lynmouth, Devon, funded by the EC.

Phase 1: 300kW single 11m diameter rotor system will only generally operate with the tide in one direction; cost £3.3 million.

See photograph below:

Phase 2: 750 to 1200kW will function with the flow in both directions cost approximately £4.5m including grid connection.

Phase 3: 2004-2005: Installation of the first small farm of tidal turbines about 4MW to 5MW - partly self financing through revenue generated from sale of electricity.

The candidate included an artist's impression of a turbine farm at this point – this was taken from the website referenced below, and has been omitted for copyright reasons. Artist's impression of turbine farm (image © marine current turbines ltd. fujitaresearch.com9)	
Costs of Tidal Power Although the fuel for tidal power stations is free, capital and maintenance costs are high. This is the reason why the old tidemills disappeared. According to WEC[2] "Tidal energy projects based on barrages are capital-intensive with relatively high unit costs per installed kilowatt (>£ 1500/kW)."	Although, as stated here and on page 11, the costs of the fuel are free, the fuel is not consumed in the conventional sense there is a detailed
The kilowatt-hour (kWh) is a unit of energy usually used to measure electricity. It is equivalent to 1kW of power used for 1 hour of time. energy (kWh) = power (kW) x time (hours) 1 kilowatt-hour is the energy used by a 1 kW (1000 W or 1000 J s^{-1}) device, running for 1 hour (3600 seconds), On an electricity bill, 1 kilowatt-hour is called a 1 unit. 1 kilowatt-hour is equal to 3.6 megajoules (MJ).	discussion of the costs, and comparisons are made with other renewable fuels. Comparisons with non- renewables are more sketchy hence the overall score for strand
1 kW generates 24 x 365 = 8760 kWh in a year, or 87600 kW h in 10 years assuming maximum production for all that time. If the £1500 is written off over ten years then each kWh would cost 1500.00/87600 = 0.17 p in capital costs. This compares to a retail price of electricity of typically 6 or 7 p per unit.	AO2a is **4** out of a maximum of 5 marks.

<u>Comparison with other methods</u> How much energy can be generated from a tidal energy scheme depends on where it is, and varies with as the tide ebbs and floods each day; and between neap and spring tides. It is, however, highly predictable. Other renewable energy sources include wind, solar, hydroelectricity, wave, geothermal and biomass. The efficiency of a system is the percentage of the energy in the fuel is turned into useful energy. This works well when applied to a system that uses up a fuel, for example a fossil fuel. For renewable sources of energy the issues relating to efficiency are different because a fuel is not being consumed. They include space occupied, energy payback and cost.[1] One source[1] gives the following efficiencies: A large windfarm on a good site – 40%, A large hydroelectric scheme – 85% Photovoltaic Solar Cells – 16% The largest tidal power station generates 240 MW A large Coal fired station can generate as much as 1000 MW Nuclear Power stations typically generate several hundred MW Today, hydropower provides about 19% (2650 TWh/yr) of the world's electricity supply.[2] A total of 853 wind turbines currently produce 405 megawatts of electricity in the UK, enough to meet the needs of quarter of a million homes annually[7] Scrobie sands, off the Norfolk coast is one of the wind farms largest at 60 MW. Mablethorpe, in Lincolnshire is slightly larger at 67 MW. One of the largest solar power stations is the 12 kW photovoltaic array powering the Centre for Alternative Technology, near Machynlleth.[1]	Although reference is made to different scales of production no real comparison is made between large and small scale. This is compensated by the detailed volume of well researched and referenced detail. (It is noted that all the research has been done on websites, and a more varied range of sources might have been recommended.) Strand AO2b therefore scores **4** out of 5 marks.

Advantages of tidal power Fuel is free Renewable Reduces need for fossil fuels No liquid or solid pollution Little visual impact New areas of sheltered water, attractive for fish, sea birds, seals and seaweed Shelter the coast, useful in harbour areas Tides are predictable Disadvantages of tidal power Barrier to shipping Environmental concerns High capital and Maintenance costs Only provides power for about 10 hours each day Very few suitable sites	
References 1. www.cat.org.uk 2. WEC Survey Of Energy Resources 2001 - Hydropower http://www.worldenergy.org 3. Belfast Energy Agency. http://www.belfast-energy.demon.co.uk/renewtech.htm 4. Tidal Power Systems. http://reslab.com.au/resfiles/tidal/text.html 5. The Rance Tidal Barrage, http://www.pteratunes.org.uk/OU/Tidal/RanceTidalBarrage.html 6. http://www.blatchingtonmill.org.uk/subjects/science/Science/KS4%20Module%205%20Revision%20list.htm 7. BWEA.com 8. http://www.eling.aaugonline.net/notready/working/work.html 9. http://www.fujitaresearch.com/reports/tidalpower. 10. http://www.esru.ac.uk Bibliography http://www.darvill.clara.net/altenerg/index.htm http://www.darvill.clara.net/altenerg/index.htm www.bluenergy.com http://www.alternative –fuels.com/tidal.html	