T206/C

The Open University

Level 2 Course Examination 2005

ENERGY FOR A SUSTAINABLE FUTURE

Tuesday 11th October 2005 **10.00 am - 1.00 pm**

Time allowed: 3 hours

Answer **ALL** questions in **Part A** and any **TWO** in **Part B**.

Each question in Part A carries 6 marks (48 marks in total) and each Part B question carries 26 marks (52 marks in total). You are advised to spend **five minutes** looking through the paper before you start. You should then spend no more than **one hour and twenty minutes** on Part A. This leaves **one and a half hours** for Part B, and **five minutes** at the end to check through your answers.

At the end of the examination

Check that you have written your personal identifier and examination number on **each** answer book used. **Failure to do so will mean that your work cannot be identified**.

Put all your used answer books and your question paper together with your signed desk record on top. Fix them all together with the paper fastener provided.

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Part A

*Answer **ALL** questions in **Part A**.*

Question 1 The second half of the twentieth century saw major changes in the roles of the three fossil fuels in the UK. For each of the following, outline the main changes in *production* and in *consumption* over this period, and comment briefly on the reasons for these changes.

(a) Coal

(b) Oil

(c) Natural gas

(6 marks)

Question 2 Table 1 (below) shows data for two power stations: a fairly old coal-fired plant and a combined-cycle gas turbine (CCGT) plant. For each of these, the table gives the rate of fuel input needed for an electrical output of 100 MW, the energy content per tonne of fuel, and the mass of carbon in the CO_2 released to the atmosphere in producing one gigajoule of heat.

Table 1

plant type	electrical output /MW	fuel input rate /tonnes per hour	energy content /GJ per tonne	carbon released /kg per GJ
coal-fired	100	40	26	24
CCGT	100	14	55	14

(a) Use the appropriate data from the table to calculate the overall fuel-to-electricity efficiency of each plant.

(b) Show that the coal-fired plant releases more than twice as much carbon as the CCGT plant, for the same electrical output.

(6 marks)

Question 3 *(a)* Describe what is meant by a *hydrogen economy*.

(b) If the hydrogen is produced from fossil fuels, the additional CO_2 produced in the conversion processes could lead to a greater total production of CO_2 than if the original fossil fuels were used directly. Nevertheless, the hydrogen economy is regarded as a means of reducing the amount of CO_2 released into the atmosphere. Briefly explain why.

(c) Suggest two reasons for the view that a significant change towards a hydrogen economy can only be regarded as a medium- or even long-term measure.

(6 marks)

Question 4 Describe with the aid of a suitably labelled diagram or diagrams the main elements of a roof-mounted pumped solar hot water system for a house. Your description should include the essential features of both the collector and the circulation system.

(6 marks)

Question 5 *(a)* The following formula may be used to estimate the average annual electrical output, (E), in kilowatt-hours per year, from each turbine in a group of wind turbines.

$$E = 3.2 \times V_m^3 \times A_t$$

State the meanings of the symbols V_m and A_t.

(b) A wind power project is being considered, for a site with a mean annual wind speed of 8.6 m s^{-1}. The turbines will have a diameter of 80 m. Use the above relationship to show that the annual output per turbine would be about ten million kilowatt-hours.

(c) The average power delivered by the wind at the proposed site is 800 watts per square metre. Calculate the total energy delivered to each turbine in one year, and comment briefly on the relationship between this input and the above output.

(6 marks)

Question 6 Table 2 below shows estimated capital costs and running costs for two types of power station: a combined cycle gas turbine (CCGT) and a tidal stream device. The table also gives the annual borrowing repayments per £1000 of capital cost, using conventional annuitizing methods, assuming a 20-year lifetime and 8% discount rate. The average capacity factors of the plants are also shown.

(a) Use the given data for each type of plant to calculate:

(i) The annual capital repayment per kW of installed capacity.

(ii) The annual output in kWh per kW of installed capacity, noting that there are 8760 hours in one year.

(iii) The capital repayment in pence per kWh of output.

(b) Show that, on the assumptions in the table, the total cost per kWh of output for the tidal plant is about 50% higher than for the CCGT plant.

Table 2

plant type	CCGT	tidal stream
CAPITAL COST AND ANNUAL PAYMENT		
capital cost per kW of installed capacity	£300	£1200
annual payment per £1000 of capital cost	£102	£102
CAPACITY FACTOR AND OUTPUT		
capacity factor	80%	40%
OTHER COSTS AND TOTAL COST		
operation and maintenance costs (p per kWh of electricity generated)	0.30	1.00
fuel cost (p per kWh of electricity generated)	2.20	nil

(6 marks)

Question 7 *(a)* One factor that influences the energy consumption of lighting systems is 'lamp efficacy'. Define this term.

(b) List *four* other factors which influence the energy consumption of lighting systems.

(6 marks)

Question 8 Describe and briefly discuss the advantages and disadvantages of any **TWO** alternatives to petrol and diesel as energy sources for passenger road vehicles.

(6 marks)

End of Part A

Part B

*Answer any **TWO** questions in **Part B**.*

Question 9 An ageing 1000 MW coal-fired power station is due for closure, and its role in the National Grid makes a replacement necessary. The two options being considered are a modern coal-fired plant, with carbon sequestration, and a nuclear plant. The location is close to the site of a major coal mine, now closed, and there are suggestions that this might be developed for carbon sequestration or for nuclear waste storage.

Write a paper discussing the relative merits of the two options. It should consider the technical, economic, environmental and social aspects and will be addressed to the public at large. However, the views of the local population will be particularly important, and emphasis should be given to their likely concerns.

(26 marks)

Question 10 *(a)* Describe the projection of future world conventional oil production that is known as 'Hubbert's Peak', and briefly explain the reasoning that leads to it.

(b) Discuss the potential of other sources of liquid fuels as replacements for conventional oil, considering in particular the environmental, economic and strategic implications of each option.

(26 marks)

Question 11 In their 1999 review *New and Renewable Energy in the UK*, the Department of Trade and Industry suggested that there could be a considerable contribution to UK electricity consumption from photovoltaics and energy crops by 2025.

- 0.5 TWh y^{-1} from building-integrated PV at a cost of less than 7.0 p kWh^{-1}
- 33 TWh y^{-1} from energy crops at a cost of less than 4.0 p kWh^{-1}

Discuss the practical and environmental problems that might arise in achieving such contributions from these two technologies by this date. Your discussion should include rough estimates of the likely building or land areas involved, and should conclude with a general comparison of the relative merits of the two options. (Total UK electricity demand in 2003 was approximately 350 TWh y^{-1}.)

(26 marks)

Question 12 When the House of Lords discussed renewable energy resources on 24 March 2005, the Department of Trade and Industry Minister, Lord Sainsbury, commented that…

> *the cost of wave [and tidal] energy is still orders of magnitude higher than any other at the moment. At about 15 to 20p per kilowatt hour, it is still very expensive.*

This is very much in line with the Government view in 1982, when support for the UK wave energy program was severely scaled down by the then Department of Energy.

Has nothing changed during the past twenty years? Consider this question in terms of wave energy developments (in the UK or elsewhere) and changes in the overall energy situation of the UK. In conclusion, explain whether in your view Government policy on support for wave power should be different this time, or not.

(26 marks)

Question 13 A college building currently uses mains electricity and is heated by natural gas. In energy terms, its annual electricity demand is about two-thirds of its annual heat demand. The peak electricity demand during the day is about 200 kW. The gas boilers must soon be replaced, and the college authorities are considering changing to a small scale CHP system. Write a briefing note for the authorities explaining the environmental advantages and the factors that they will need to take into account in deciding whether or not to make this change.

(26 marks)

Question 14 In the USA in the early 1980s, the installation of large wind farms was stimulated by a system of tax credits. In the 1990s the UK Government used the Non-Fossil Fuel Obligation (and, more recently, a Renewables Obligation) to accelerate the uptake of renewable energy technologies. The German Government has used a Renewable Energy Feed-In Tariff (REFIT). The European Commission has proposed a 'carbon/energy' tax on non-renewable energy to achieve the same result.

Discuss which of these (or any other) mechanisms you would adopt, and your reasons for adopting them, if you were the government minister charged with the responsibility for meeting UK national targets for energy from renewables over the next 20 years.

(26 marks)

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Examination Data Sheet

Note: This data sheet has been compiled to give useful numerical values for T206 examination purposes. As such, some of the values have been rounded to allow for the calculation of quick answers. Please consult the course text for more accurate values for non-examination use.

World Primary Energy consumption, 2000

The total annual primary energy consumption of 424 EJ is equivalent to just over 10 billion tonnes of oil per year or 200 million barrels per day oil equivalent.

Energy source	Primary Energy (EJ)	Contribution to Primary Energy (%)
Oil	146.7	34.6%
Coal	91.6	21.6%
Natural gas	90.7	21.4%
Fossil fuels sub-total	329.0	77.6%
Hydro	9.6	2.3%
Nuclear	28.0	6.6%
Biomass	48.0	11.3%
'New'* renewables	9.0	2.1%
World total	**424.0**	**100%**

* 'New' renewables comprise solar, wind, tidal, geothermal etc.

UK Primary Energy production and consumption, 2000

All data are in petajoules (PJ).

	Oil	Coal	Natural gas	Primary Electricity	Total all sources
Production	5767	820	4486	844	12017
Consumption	3147	1697	3972	891	9707

UK delivered energy by fuel type and sector, 2000

All data are in petajoules (PJ).

	Liquid fuels	Solid fuels	Natural gas	Electricity	Total all types†
Transport	2280	–	–	32	2311
Industry	267	117	722	409	1515
Domestic	136	91	1332	403	1961
Other	101	16	456	341	915
Total all sectors†	2830	223	2511	1184	**6702**

† Totals may differ from the sums of the items, due to rounding of the data.

General data

Multiplying factors

1 billion is 1000 million

prefix	symbol	multiplier	alternative
kilo-	k	10^3	1000
mega-	M	10^6	1000 kilo-
giga-	G	10^9	1000 mega-
tera-	T	10^{12}	1000 giga-
peta-	P	10^{15}	1000 tera-
exa-	E	10^{18}	1000 peta-

Other units

quantity	symbol	equivalent
1 watt	W	1 joule per second
1 kilowatt-hour	kWh	3.6 MJ
1 gigajoule	GJ	278 kWh
1 hectare	ha	10 000 m^2
1 square kilometre	km^2	10^6 m^2 *or* 100 ha
1 tonne	t	1000 kg

Physical constants

The following approximate values may be used unless otherwise specified in particular questions:

	Value	Unit
acceleration due to gravity (*g*)	10	m s^{-2} *or* N kg^{-1}
density of water	1000	kg m^{-3}
density of air at normal atmospheric pressure	1.3	kg m^{-3}
specific heat capacity of water (heat absorbed or released per kg for a temperature change of 1 °C)	4.2	kJ kg^{-1} $°C^{-1}$

Solar radiation

	Value	Unit
maximum intensity on horizontal surface at sea level with sun vertically overhead	1000	W m^{-2}
southern UK, on south-facing surface tilted at 50° …		
annual total	1000	kWh m^{-2}
monthly total, June	130	kWh m^{-2}
monthly total, December	30	kWh m^{-2}

Heat released in combustion

	Value	Unit
wood (air-dry, 20% moisture)	15	MJ kg^{-1} *or* GJ t^{-1}
municipal solid wastes (commercial, industrial and domestic)	9	MJ kg^{-1} *or* GJ t^{-1}
natural gas (methane)	55	MJ kg^{-1} *or* GJ t^{-1}
oil	42	MJ kg^{-1} *or* GJ t^{-1}
coal	26	MJ kg^{-1} *or* GJ t^{-1}

Miscellaneous world data

	Value	Unit
population, 2000	6100	million
land area	150	million km^2
water area	350	million km^2
wind energy contribution, 2000	60	TWh y^{-1}
wind power installed capacity, 2002	30	GW
geothermal electricity contribution, 1997	80	TWh y^{-1}
geothermal heat contribution, 1997	34	TWh y^{-1}
potential annual hydroelectric resource (maximum *technically* exploitable potential)	20 000	TWh y^{-1}
potential annual wind energy resource (maximum *technically* exploitable potential)	20 000	TWh y^{-1}

Miscellaneous UK data

	Value	Unit
population, 2000	59.2	million
land area	245	thousand km^2
number of households	22	million
tidal range, Severn Estuary	12	m
annual mean wind speeds – range between modest sites and very good sites	6–9	$m\ s^{-1}$
annual average wave power – range between modest sites and very good sites	40–70	$kW\ m^{-1}$
annual yield, short rotation coppice (air-dry mass)	10	$t\ ha^{-1}\ y^{-1}$
total annual forestry residues (air-dry mass)	2	$Mt\ y^{-1}$

[END OF QUESTION PAPER]