1. A National Grid transformer in a sub-station converts 30 000 V into 230 V to power a town of 12 000 inhabitants. The transformer is 99% efficient.

Using appropriate estimates, discuss the energy consequences **for the transformer sub-station** if the efficiency is less than 100%.

---

[2]

2(a). The table below shows data about three different power stations.

Power station	Primary fuel	Efficiency (%)	Output voltage (kV)	Output power (MW)
A	coal	33	24	1400
B	gas	42	28	1100
C	uranium	33	22	1200

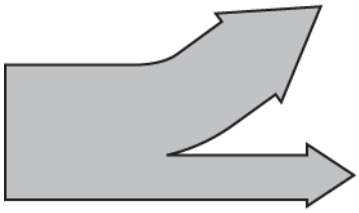
For each statement below, put a tick (?) in the **one** correct box.

	Power station A	Power station B	Power station C
The power station produces the least carbon dioxide.	☐	☐	☐
The generator produces the largest current.	☐	☐	☐
The energy produced each second from the primary fuel is smallest.	☐	☐	☐

[2]

(b). The three Sankey diagrams below describe these three power stations. The three diagrams are drawn to the same scale.

In the space under each diagram, write the letter (**A**, **B** or **C**) for that power station.



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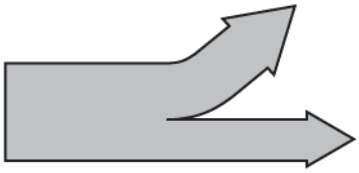

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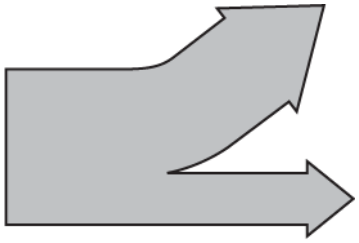


.....

[2]

3(a). A 230 V mains-powered electric drill draws a current of 2.5 A.

Calculate the power of the drill when it is in use.

power = _____ W **[2]**

(b). Another electric drill has a power rating of 600 W. Calculate the number of joules of energy transferred when this drill is in use for 5 minutes.

energy = _____ J **[2]**

(c). Calculate the energy transferred by the 600 W drill when used for 5 minutes in kWh.

energy = _____ kWh **[2]**

4. A TV set uses 500 J of energy from the mains electricity.

The TV produces 100 J of energy as sound and 300 J of energy as heat.

It also produces energy as light.

Draw and label a Sankey diagram to show the energy transfers by the TV set.

Some lines have been drawn for you.

_____

_____

_____

_____

_____

_____

[4]

5(a). A more modern TV set is 75% efficient.

The set has a power rating of 300W.

How much energy is **wasted** by the TV set in 120 minutes of watching the television?

Put (rings) around the **two** correct answers.

9 kJ	27 kJ	36 kJ	540 kJ	1620 kJ
0.0025 kWh	0.0075 kWh	0.010 kWh	0.15 kWh	0.45 kWh

[2]

(b). The electrical energy used by the TV set is generated in a power station.

(i) Complete these sentences about the production of electricity in some types of power station.

Use words from the list.

coil current electricity energy magnet

resistance turbine transformer voltage

The primary _____ source directly turns the _____ .

In the generator, the spinning _____ produces a voltage

in a _____ .

The electricity generated is distributed using a high _____ in the

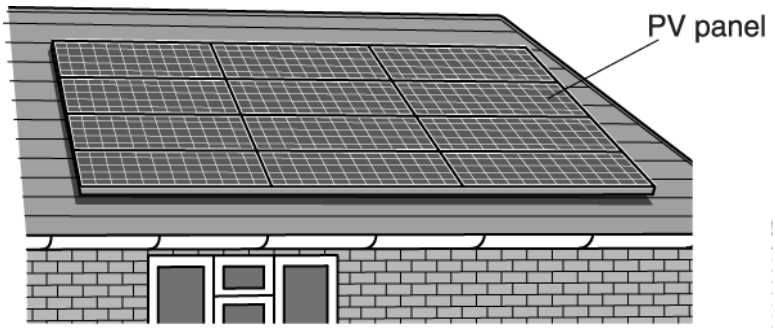
National Grid to homes and factories.

[3]

(ii) Suggest a type of power station the sentences could be describing.

_____ [1]

6. Many house-owners are putting sets of photovoltaic (PV) panels on their roofs to generate electricity during daylight. The panels work best if the roof used is facing south.



The data about the type of PV panel shown in the diagram are given in the table.

size of one panel (m × m)	1.5 × 0.8
average daily energy output of one panel (kWh)	0.6
cost per panel	£200

A family needs about 24 kWh of electricity per day, averaged out over the winter and the summer.

This family has decided to fit 12 panels on their roof to provide their energy needs throughout the year.

Discuss the advantages and disadvantages of fitting these panels to their roof.

The quality of written communication will be assessed in your answer.

---

[6]

7(a). An old fridge works for 24 hours a day, every day of the year.

It has a current of 0.63 A from the 230 V mains.

Which of the following values is the energy in kilowatt hours transferred in a year, written to two significant figures?

Assume that a year is 9000 hours.

Put a ring around the correct value in kWh.

1300 3200 1 300 000 3 200 000

[1]

(b). A modern fridge rated A++ has one-eighth of the power rating of the old fridge in **(a)**.

Calculate the money saved in a year when the old fridge is replaced by the modern fridge.

Cost of one kilowatt hour = 16 p

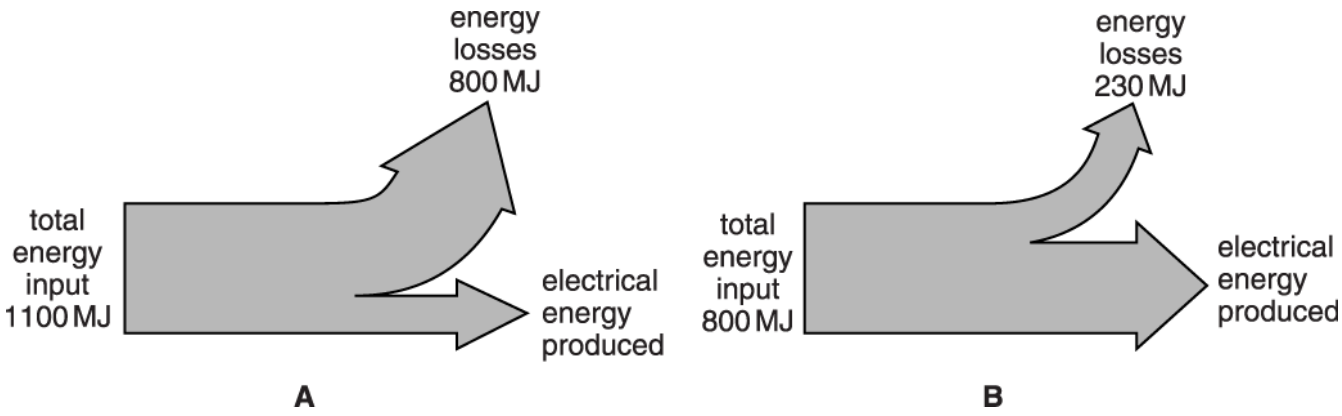
money saved = £ _____ [2]

(c). The modern fridge costs less money to use, but there are other factors to consider before replacing the old one.
Suggest and explain **one** reason why it may **not** be a good idea to replace the old fridge.

---

[2]

8. The Sankey diagrams below show the energy transfers in 1 second in two different power stations **A** and **B**.



The statements below are true for power station **A**, or true for power station **B**, or true for **both**, or true for **neither**.

Put a tick (✓) in **each** correct box after each statement.

	true for A	true for B	true for neither
It generates more than 600 MW of electrical power.	☐	☐	☐
It has an efficiency of more than 60%.	☐	☐	☐
Energy losses in one minute are more than 1×10^{10} J.	☐	☐	☐
The total energy input in one minute > 50 000 MJ.	☐	☐	☐

[3]

9(a). Here is data about the capacity and power rating of some kettles.

Kettle	Maximum volume in litres	Power rating in kilowatts
A	0.5	3
B	1	2
C	2	3
D	1.5	1.5

How many seconds will it take kettle **B** to transfer 6 kilojoules of energy?

answer _____ seconds **[1]**

(b).

(i) Which kettle will boil 1 litre of water the fastest?

answer _____ **[1]**

(ii) Justify your answer to part **(b)(i)**.

_____

_____

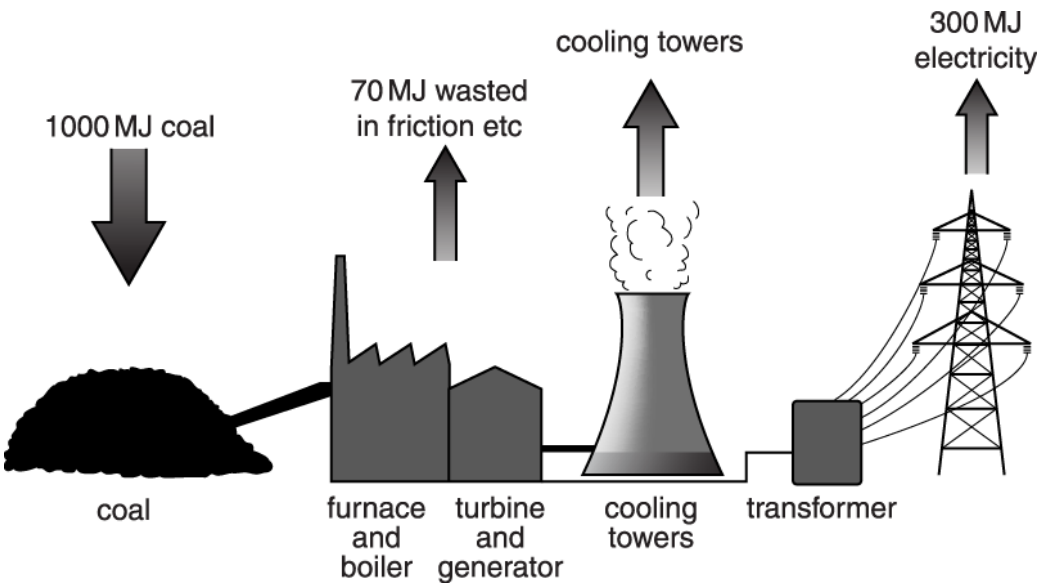
_____ **[2]**

(c). The mains voltage is 230 V.

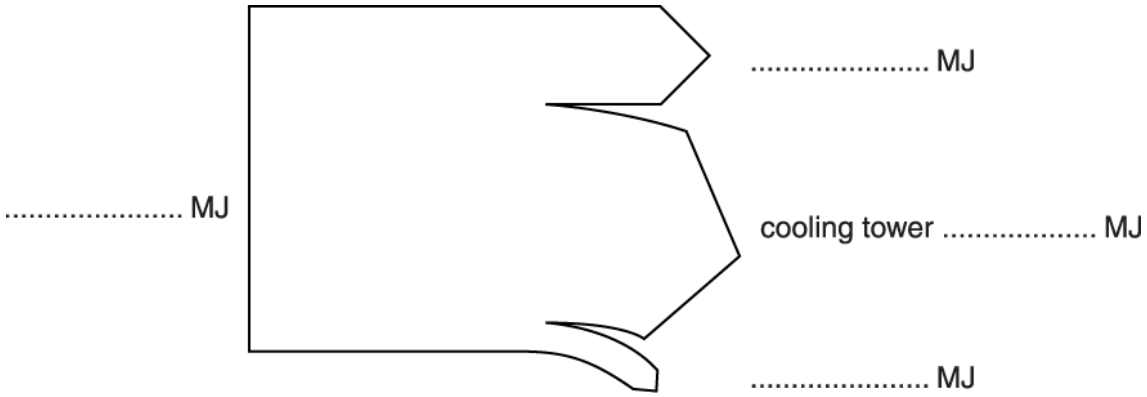
What is the current in kettle **D** when it is heating water?

current = _____ A **[2]**

10. The diagram shows the energy flow through a coal-burning power station each second.



(i) Complete the Sankey diagram to show this energy flow.



[3]

(ii) What is the efficiency of the coal-burning power station?

efficiency = _____ % **[1]**

11. For every MWh of electricity produced by burning **coal**, 550 kg of carbon dioxide are released.
To produce the same amount of electricity by burning **gas**, 180 kg of carbon dioxide are released.

A 1200 MW coal-burning power station is replaced with a gas-burning power station of the same output.

Calculate the reduction in carbon dioxide produced each day (24 h).

---

[3]

12. A camping kettle is marked 12 V 170 W. It needs 70 kilojoules to boil the water in it.
How long will it take to boil?

Put a (ring) around the nearest value.

0.4 seconds **4 minutes** **7 minutes** **70 minutes**

[1]

13. A solar farm is planned for West Wales. The data for this project are given below.

Intensity of radiation on the panels	0.9 kW / m^2
Number of solar panels	35 000
Area of each solar panel	1.2 m^2
Efficiency of the solar panels	15%

The project planners claim this solar farm can produce 7.5 MW. Use the data to check if the planners' claim is correct.

Show your working.

[3]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			Energy dissipated in transformer will result in heat up of substation. If not removed it will result in a meltdown. (1) Large amount of energy justified by estimate e.g. 1 to 5kW per person. Typical output current at 230V of 200 – 10 000 A (1)	2	
			Total	**2**	
2	a		C, A, B	2	all correct = 2, two correct = 1
	b		C, B, A	2	all correct = 2, one correct = 1 unless same answer given to all which =0 may write words, i.e. Uranium Gas Coal **Examiner's Comments** This was an objective question testing the ability to read and manipulate the data in the given table in part **(a)** and to identify the appropriate Sankey diagrams in part **(b)**; accordingly, part **(b)** was the more straight-forward and was completely correctly answered by about half of all candidates.
			Total	**4**	
3	a		230 V × 2.5 A (1); = 575 (W)(1)	2	575 with no working gets both marks
	b		600 W × (5 × 60 s) (1); = 180 000 (J) (1)	2	3000 J = 1 mark 180 000 / 180 k / 0.18 M with no working gets both marks

Question			Answer/Indicative content	Marks	Guidance
	c		0.6 kW × (5/60) h (1); = 0.05 (kWh) (1)	2	Accept for 1 mark answer with just 1 error in conversion W ? kW or min ?h for 1 mark, e.g. 3, 5 or 50 3000 kWh gets no marks accept intermediate rounding 5/60 = 0.083 h ? 0.048 (kWh) 0.05 with no working gets both marks
			Total	6	
4			arrow with three heads (1) scale correct (1) max 2 marks for out put labels (100J) sound, (100J) light (300J) heat / waste	4	 e.g. input 5 units, outputs 3 units, 1 units, 1 units 2 marks = 3 outputs correct 1 mark = 1 output correct Examiner's Comments It was disappointing to see that many candidates did not realise that a Sankey diagram should be drawn to scale. Weaker candidates presented their diagram with only two arrows: one for the useful energy and one for the wasted energy as if they were considering efficiency.
			Total	4	

Question			Answer/Indicative content	Marks	Guidance
5	a		540kJ or 0.15 kWh (1) an equivalent pair of values chosen (1)	2	**note**: 540 KJ and 0.15kWh will score 2 marks equivalent values: 9 kJ = 0.0025 kWh 27 kJ = 0.0075 kWh 36 kJ = 0.010 kWh 540 kJ = 0 15 kWh 1620 kJ = 0.45 kWh **Examiner's Comments** Very few candidates successfully calculated the energy wasted, even in one of the units, though a few did manage to convert an incorrect value in joules into a correct equivalent value in kWh. Surprisingly many candidates failed to circle two answers.
	b	i	• energy • magnet • coil • turbine • voltage	3	all correct = 3 marks 3 / 4 correct = 2 marks 2 correct = 1 mark **Examiner's Comments** The question, which is a variation on a common themed question for this paper on the sequence of operations in a power station, was not answered well. The most common errors involved some confusion around turbines, magnets and coils.
		ii	hydroelectric / wind	1	**accept** tidal / wave / geothermal **Examiner's Comments** Only the stronger candidates scored this mark, with many suggesting nuclear or 'electrical power station'.
			Total	**6**	

Question			Answer/Indicative content	Marks	Guidance
6			**(Level 3)** Uses a correct, relevant calculation(s) and discusses both advantages and disadvantages. Quality of written communication does not impede communication of the science at this level. (5–6 marks) **(Level 2)** May quote data without calculation. Attempts a balanced argument of advantages and disadvantages OR an unbalanced argument supported by calculation. Quality of written communication partly impedes communication of the science at this level. (3–4 marks) **(Level 1)** Qualitative discussion of one side of the argument only. May not attempt a balanced argument. Quality of written communication impedes communication of the science at this level. (1–2 marks) **(Level 0)** Insufficient or irrelevant science. Answer not worthy of credit. (0 marks)	6	This question is targeted at grades up to C Indicative scientific points may include: Ignore confusion between PV and solar heating panels. Advantages • No CO_2 / no pollution produced / won't harm environment / eco-friendly • Renewable / will not run out • Power cuts won't affect them • Reduces the household bill • Can get money for excess electricity • The electricity produced is free Disadvantages • Doesn't produce all of the electricity required / less electricity in winter when needed most • Needs lots of panels / not enough panels for whole bill • Initial cost / outlay of money / takes time to pay back • Variable output with light / clouds / winter / night • Other sources of energy needed • Heavy / damaging on roof • Ugly • Maintenance needed Data calculations • 40 panels required to provide all the electricity • 12 panels would produce 12 X 0.6 = 7.2 kWh not 24kWh / Energy bill is reduced by a third • Total area of 12 panels is = 12 × 1.5 × 0.8 = 14.4 m^2 • The cost of 12 panels is 12 × £200 = £2400. Use the L1, L2, L3 annotations in Scoris; do not use ticks. Examiner's Comments This extended response 6-mark question was generally well done, with many

Question			Answer/Indicative content	Marks	Guidance
					candidates able to discuss pros and cons of installing the panels in both environmental and cost terms, supporting their answer by relevant calculations using the data provided.
			Total	6	

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>7</td><td>a</td><td></td><td>1300</td><td>1</td><td>Examiner's Comments

The multi-stage calculation in part (a), with a number of hurdles to cross, meant that only about one candidate in six had the correct answer, which is less than guesswork as there were four options to choose from.</td></tr>
<tr><td></td><td>b</td><td></td><td>calculates power saving in kWh
7/8 the answer to (a)

OR

calculates new fridge power use in kWh
1/8 the answer to (a) (1)

Then:
calculates the cost saving from above with due allowance for rounding errors (1)</td><td>2</td><td>allow 7/8 or 1/8 multiplied by a recalculation using the current (0.63A) and voltage (230V)

<table>
<tr><td></td><td colspan="4">power saving in kWh</td></tr>
<tr><td>Answer to (a):</td><td>1300</td><td>3200</td><td>1 300 000</td><td>3 200 000</td></tr>
<tr><td>7/8</td><td>1137.5</td><td>2800</td><td>1 137 500</td><td>2 800 000</td></tr>
<tr><td>1/8</td><td>162.5</td><td>400</td><td>162,500</td><td>400 000</td></tr>
<tr><td></td><td colspan="4">cost saving</td></tr>
<tr><td>saving</td><td>£182</td><td>£448</td><td>£182 000</td><td>£448 000</td></tr>
</table>

unexpected results: calculate to check candidate's use of own figures. Watch for POT error kilowatts to watts and pence to pounds

Examiner's Comments

In (b) ‘error-carried-forward’ from an incorrect choice in (a) allowed full marks for the correct processes, but surprisingly few realised that saving £182 000 in a year was not likely – this should have stimulated them to go back and reconsider their choice in (a).</td></tr>
</table>

<table>
<tr><th colspan="3">Question</th><th>Answer/Indicative content</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td>c</td><td></td><td>suggestion why replacing fridge is not a good idea (1)

explanation or further detail (1)</td><td>2</td><td>mark suggestion and explanation as a pair
e.g. capital cost (1); may not have that much cash to hand (1)
e.g. wasteful of resources (1); disposing of something that works (1);
e.g. pollutes environment (1); contains toxic chemicals (1)

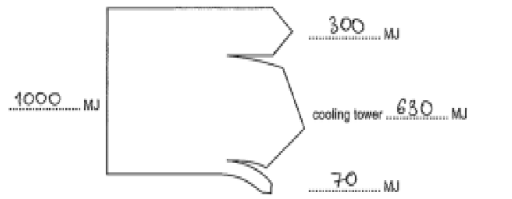
Examiner's Comments

Reasons for not discarding the old fridge in (c) were often sensible, but many did not attempt this part having found the earlier, mathematical parts too demanding – they should have realised that this part was independent of them.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>5</td><td></td></tr>
<tr><td>8</td><td></td><td></td><td><table><tr><th>for A</th><th>for B</th><th>neither</th></tr><tr><td></td><td></td><td>?</td></tr><tr><td></td><td>?</td><td></td></tr><tr><td>?</td><td>?</td><td></td></tr><tr><td>?</td><td></td><td></td></tr></table></td><td>3</td><td>mark by rows
all correct = 3
three correct rows = 2
one or two correct rows = 1

Examiner's Comments

Most were able to do the maths necessary for one or two rows of the table, with only a few per cent completing it all.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>3</td><td></td></tr>
</table>

Question			Answer/Indicative content	Marks	Guidance
9	a		3 (s)	1	**Examiner's Comments** This question was usually answered correctly. The most common incorrect responses were '2', '6' and '12'. Most seemed to recognise that the power rating was relevant, but didn't know how to relate this to energy.
	b	i	**C**	1	**Examiner's Comments** There were a whole range of incorrect answers. Probably the most common was A
		ii	(**A** or **C** has) the highest power / the fastest energy transfer (1) **A** only has a capacity of 0.5 litres, so would have to be filled which would add extra time so more time than **C** (1)	2	No mark if answer to bi is **B** or **D** **Examiner's Comments** Many just stated facts from the table and so reference to power was not comparative (e.g. it has a power of 3kW as opposed to the highest power.). A very small number were able to explain why C would be faster than A. Many incorrectly suggested that A would be faster as it holds less water and so the power would be more effective on that smaller volume.
	c		1500 / 230 6.5 (A)	2	**ignore** extra sig figs correct numerical answer gains both marks **allow** 1 mark for 1.5 / 230 or 0.0065 **Examiner's Comments** Many candidates were unable to correctly rearrange the formula and so inverted power and voltage (230/1.5) or multiplied power and voltage. Of those able to rearrange, many left the power in kilowatt without converting to watts and so could only gain 1 mark. It is clear that most candidates do not appreciate the sizes of currents flowing in various appliances.
			Total	6	

Question			Answer/Indicative content	Marks	Guidance
10		i		1	
		i	cooling tower – 630 as second label down on right (1) **max** 2 marks (coal) 1000 (MJ) (electricity) 300 (MJ) (wasted in friction) 70 (MJ)	2	3 correct = 2 marks 2 correct = 1 mark 0 or 1 correct = 0 marks **Examiner's Comments** Most candidates were able to calculate the value for the cooling tower as 630 MJ and state the 1000 MJ input. The most common error was in mixing up the '300' and '70' as they had not looked at (or not recognised the significance of) the relative sizes of the arrows on the Sankey diagram.
		ii	30	1	**do not accept** 0.3 **Examiner's Comments** Generally well answered. Incorrect responses were usually as a result of picking out one of the other numbers (e.g. 63% or 70%)
			Total	**4**	

Question			Answer/Indicative content	Marks	Guidance
11			typical approach for each PS, 1 day ? 24 h × 1200 MW = 28 800 (MWh) (1) **And then either:** mass CO_2 produced by coal-burning PS = 28 800 × 550 kg = 15 840 000 kg / 1.584 × 10^7 kg (1) mass CO_2 produced by gas-burning PS = 28 800 × 180 kg = 5 184 000 kg / 5.184 × 10^6 kg so reduction = 10 656 000 kg / 1.07 × 10^7 kg (1) **or:** Mass difference per MWh = 550 ? 180 = 370 kg (1) Mass difference per day = 370 × 28800 kg =10 656 000 / 1.07 × 10^7 kg (1)	3	valid alternative approaches should be credited (look for 2 multiplications and a subtraction in any order) bald correct answer 10 656 000 kg / 1.07 × 10^7 kg gets all 3 marks. Two common wrong answers bald answer of 444 000 kg/ 440 000 kg / 4.4 × 10^5 kg gets 2 marks (omits multiplying by 24 hours) bald answer of 8880 kg/ 8900 kg gets 2 marks (omits multiplying by 1200 MW) **ecf throughout** If 24 h not used, energy = 1200 MWh Mass from coal = 660 000 kg mass from gas = 216 000 kg reduction = 444 000 kg Can get this mark for gas-burning PS if done first If gas done first, this mark is mass from coal + subtraction **Units needed in final answer** **Examiner's Comments** ?The calculation in this question had a high omit rate; this is probably due to a combination of two factors – it involved a multi-stage calculation and it is the last question in the paper. Candidates who laid out their work systematically had a better chance of getting marks as it was clear which stages of the process they had managed correctly. A large number omitted to scale up for 24 hours, or to scale up for 1200 MW – each of these approaches, if done correctly in other aspects, gained 2 of the 3 marks.
			Total	**3**	

Question			Answer/Indicative content	Marks	Guidance
12			7 minutes	1	Examiner's Comments It was surprising how many candidates expected the kettle to boil in 0.4 seconds, or were happy that it would take over an hour to boil.
			Total	1	
13			incident power = 0.9 × 35 000 × 1.2 m^2 = 37 800 (kW) (1); electrical output = 37 800 W × (15/100) = 5670 (kW) (1); = 5.670 MW (< 7.5 MW) (1);	3	(total Power) (efficiency) (conversion kW to MW) bald answer 5.7 MW would get all 3 marks **apply ecf throughout this question** Examiner's Comments The strongest candidates typically obtained two of the three marks in this multi-stage calculation, typically making an error in one stage. Weaker candidates tended not even to attempt the question.
			Total	3	