ENV-2D02 ENERGY CONSERVATION 2006

Previous Exam Papers – Part 2

(2000 onwards)

This handout contains the papers set in 2000 and subsequent years. You should read the guidance notes about questions and their relevance in Part 1.

In 2000, the Course Code was ENV-2B14 and in 2002 and 2004 it was ENV-2D02.

The exam papers in this handout are also available separately from the Course WEB Page.

See http://www2.env.uea.ac.uk/gmmc/env/energy.htm

UNIVERSITY OF EAST ANGLIA

School of Environmental Sciences

Spring Semester Examination 2000

ENERGY CONSERVATION

ENV-2B14

Time allowed: Two hours

Answer **THREE** questions, **ONE** question from **EACH** section.
Questions in Section **C** carry **TWICE** the number of marks as those in Sections **A** or **B**.

Answer **EACH** question in a **SEPARATE** answer book.

Do not turn over until you are told to do so by the Invigilator.

This includes Model Answers for many of the questions

ENV-2B14 - ENERGY CONSERVATION - 2000

SECTION A (25% - 30 minute questions)

1. Review the changes which have taken place in electricity tariffs over the last 20 years paying particular attention to the changes since September 1998.

Electricity prices reach an all time high in real terms at the end of the 1970's being approximately 15 – 20% above current prices. There was limited change in the 1980's prior to Privatisation on 1st April 1990. At that time OFFER the Electricity Regulator was appointed to oversea prices. In 1999, OFFER was merged with OFGAS (the corresponding Gas Regulator) forming OFGEM – the Office of Gas and Electricity Markets. An aim of privatisation was to introduce competition and thereby drive down prices, but the full effects of Privatisation of electricity were not to be seen by the domestic customer until September 5th 1998 when the first areas of the UK (Including Norwich) were deregulated.

At privatisation, the Electricity Supply industry was split into generators (4 of them – e.g. PowerGen, National Power) and the Regional Electricity Companies (RECs) who are the regional suppliers. Large consumers (> 1MW), did not have to purchase their electricity from the local REC, but could shop around, the most spectacular coup being Yorshire Electricity winning the contract to supply London Airport. In 1994, the threshold was reduced to 100 kW and that encompassed small businesses, school, public buildings etc. During the period, the domestic prices were regulated by OFFER according to the formula

RPI – X + F + E

Thus the price from one year to the next changed by the above formula. X was set by the regulator and was greater than the RPI which meant that post 1990 prices began to fall. F represents the fossil fuel levy initially to subsidised nuclear and renewables, but this levy was first introduced at privatisation but has been progressively reduced with the last nuclear subsidy going in 1998. The inclusion of F meant that for a while after privatisation, electricity prices actually rose. The E factor (or Efficiency factor) may be levied to promote energy efficiency measures – e.g. low energy light bulbs etc. Though the F factor has reduced significantly, E is set to treble to around £3.60 by the end of 2000, however, other savings should mean that customers do not actually see a rise. The X parameter is still fixed by the regulator, but is likely to disappear as competition becomes fully established.

Prices paid for electricity were partly dependent on the operation of the Electricity Pool in which generators bid to supply electricity with those bidding the cheapest actually generating. Following the discussion documents of July 1999 and October 1999, New Electricity Trading Arrangements are proposed to start from November 2000. This will involved bidding from the demand side as well a the supply side and it is predicted that the cumulative saving for domestic customers will be £1.5 billion pounds.

The intervention of OFFER on a number of occasions during the 1990's following abuse of the POOL system has lead to one off rebates or the X factor remaining high. In addition, both PowerGen and National Power were obliged to sell power stations to increase the number of bidders into the Pool. This number stands at around 20 now compared to the 4 at Privatisation.

Deregulation to the domestic market showed a significant drop in prices as any REC, or for that matter independent supplier can offer electricity anywhere in the country. The price consists of

2. The preamble to the Guidance Notes relating to the 1994 Building Regulations begins with the statement:

> *"The prime aim of Part L is now seen to be concerned with environmental issues including the reduction of CO2 emissions."*

Discuss how effective the current Building Regulations are in achieving this aim.

NOTE: The answer below was relevant in 2000. After April 2002, reference to the new regulations would be expected.

Up to this point, the overall requirements of the Building Regulations are in general attempting to address the prime aim. However, the cost of the fuels has to be included, and for some inexplicable reason, the standing charge for electricity can be omitted, but that for gas has to be included, and further more, standard values as relevant in 1994 must be used. This means that with a standing charge of £38 for gas, the cost for gas heating could well be more than other forms – particularly oil where no standing charge applies. The SAP rating is finally determined as an Energy Cost Factor in terms of £/m^2 deflated by a declared Energy Cost Factor Deflator to obtain the SAP rating. The anomaly arising here is that oil will typically increase the SAP rating by 5 and yet the emissions will be significantly worse. Equally, switching from mains gas to bulk tank LPG which would have the same effect in energy and environmental terms will reduce the SAP rating by as much as 20.

compared to the current regulations.

The SAP rating is intended as a measure of energy efficiency and is on a scale rising from 0 (as very poor) to 100 (very good). Technically because of the formulation of the rating to allow for economic issues it is possible for this rating to exceed 100 and in fact reach a maximum of 115. This last aspect was to allow the building industry to achieve 100 without an excessive amount of new developments, and this will tend to place a damper on future improvements in this area

The relevant U-values over time have been

	1990	1985	1976
External Wall	0.45	0.6	1.0
Roof	0.25	0.35	0.6
Floor	0.45	0.6	1.0

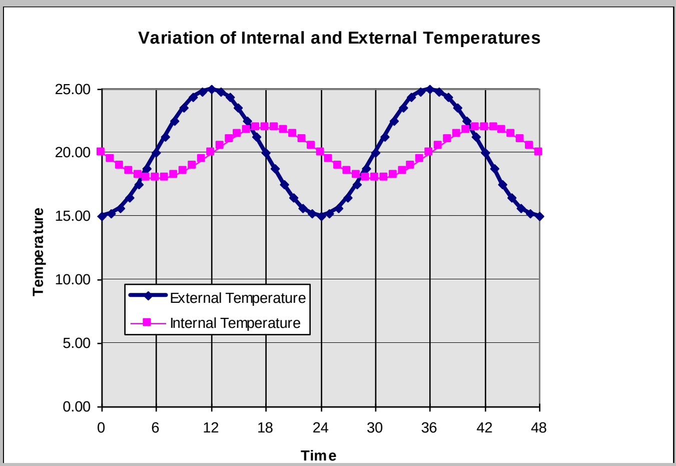
The 1994 regulations are similar to the 1990 in terms of U-Value except they now specify a maximum U-value for windows which for the first time means that all windows MUST be double glazed. However, the issue is confused by allowing houses with a SAP rating exceeding 60 to conform to those maximum values, but impose more stringent U-Value targets (e.g. 0.35 for floors) for SAP ratings < 60 (i.e. for the house performing less well). Essentially this means that there is no overall incentive to improve insulation as installation of a more efficient heating appliance could raise the SAP rating by up to 10 without the need for improved insulation. Since the appliance will have a lifetime of 15 – 20 years at best, as opposed to insulation which will have a life span 5+ times that, this relaxation of U-Value standards for the higher performing houses will not reduce energy use, and consequential emissions as effectively as they might.

The 1994 Regulations, do not specify a ventilation rate – and indeed this would be difficult to enforce unless heating in the UK moved to hot air systems. On the other hand, the regulations do specify standard procedures by which the ventilation rate may be determined, and in this respect this represents a noticeable improvement.

3. (a) Describe how energy use and temperature vary in a house when the space heating is controlled by a time switch.
(b) What disadvantages are there from time-switching?
(c) Compared to continuous heating, poorly insulated houses save proportionally more energy than well insulated ones when the heating is controlled by a time-switch. Explain why this is so.

Normal heat loss calculations assume steady state conditions and the heat loss from a building is directly proportional to the temperature difference between the inside and outside of the building. Normally the internal temperature is controlled by a thermostat which will adjust the boiler output to ensure that this temperature is maintained. In reality, domestic boilers do not have much control on output, they are either on or off. Thus as the demand for heat reduces, the proportion of the time the boiler in on will fall rather than the boiler output adjusting to demand.

The above steady state approach does not allow for storage in the buildings which can be considerable and cause a lag of up to 6 – 12 hours in the peak temperature as well as a significant reduction in the amplitude.



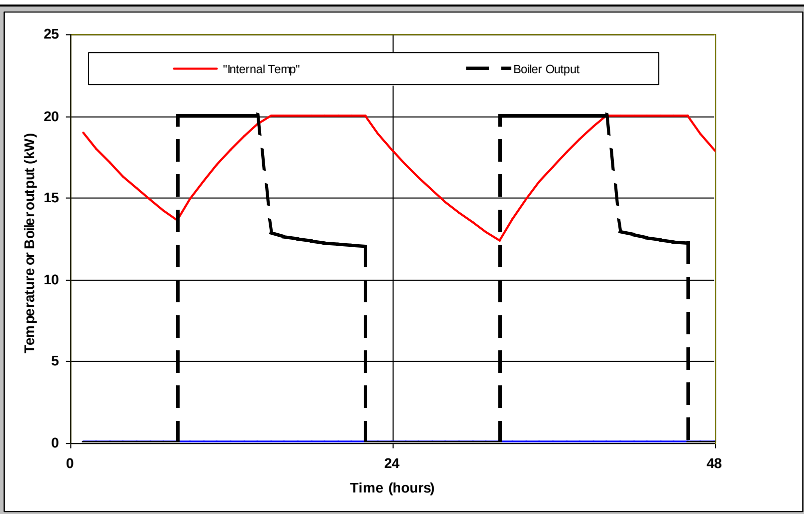
The above figure illustrates the response of a house to a sinusoidally varying external temperature illustrating a lag of 6 hours. Buildings which are more massive will have longer lag times than buildings of lightweight construction.

When the heating regime is controlled by a time-switch, the internal temperature will fall exponentially once the heating has been switched off. When the heating comes back on again, the temperature will rise exponentially until the thermostat setting is reached after which the internal temperature will remain essentially constant.

The boiler output responds immediately it switches on by providing its full output rating until the thermostat temperature is reached. Thereafter its output reduces and would ultimately stabilise at the steady state level. Typically it would take around 7 – 10 days before such stability is reached well in excess of the normal time switching regime. As normal boilers cannot regulate, the boiler output curve in reality reflects the proportion of the time the boiler is actually on. Thus it will be continuous initially, but then the ON periods will decrease and OFF periods increase.

A further complication is that real thermostats have two settings – typically +/- 1^{o}C and thus once the temperature reaches the thermostat level it will overshoot by 1^{o}C when the boiler will cut off and the temperature will then fall to 1^{o}C below the thermostat setting before the boiler cuts in again.

SECTION B (25%)



he key disadvantage from time-switching is the requirement for the boiler output to be greater than the design steady state output. Typically it will be 50% - 100%, and if there is insufficient margin, the temperature will take a long time to reach the thermostat level. Indeed if the output is only marginally above the steady state output, it is unlikely that the thermostat setting would ever be reached.

The saving from time switching can be estimate from the difference in the mean internal temperature from the external temperature. This can be compared to the internal temperature at the thermostat level in a steady state case.

In a well insulated house, the temperature falls by only a few degrees when the boiler is off, and typically the mean temperature will be only 1^oC below the thermostat setting. On the other hand in a poorly insulated house, the temperature in the OFF period falls much more and the mean temperature may be 3 – 4^oC below the thermostat setting. Thus a poorly insulated house will save PROPTIONALLY less energy by time switching than a well insulated one, The latter house, of course will consume less energy in absolute terms.

4. Describe, with the aid of flow diagrams, the processes that must be considered in an Energy Analysis study of the production of a primary material such as glass or steel. [30%]

Following the installation of a new plant, the board of a glass making company is concerned at the proportion of glass rejected and recycled because of flaws and cracks. The company want to reduce this to 5% from the current 10%. As energy manager you are asked to review the operating procedures and report on the potential energy savings that might arise from changing the reject proportion.

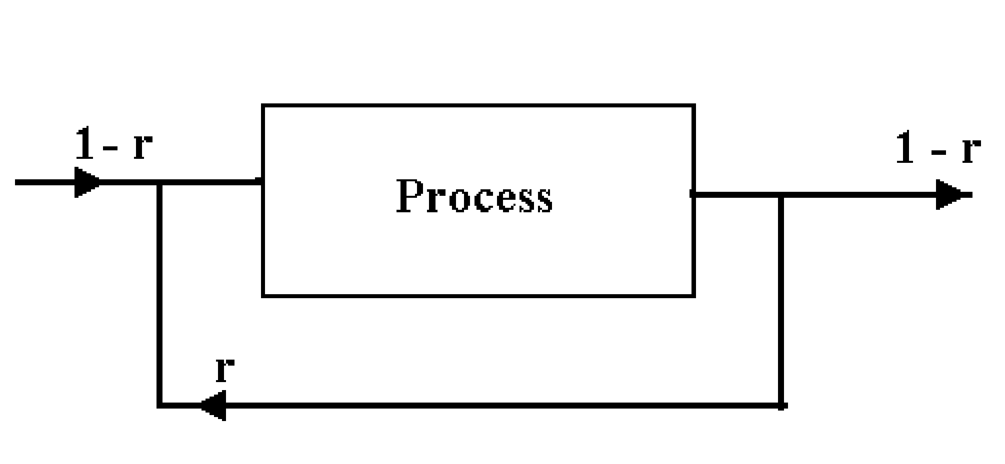
Your studies show that the energy required in the process varies with the proportion recycled and has the following empirical relationship:

E = 70 + 187.5. (0.4 - r)2 and is valid up to 40% recycling

where E is the energy requirement expressed as a percentage of that required with no recycling, and r is the proportion of material recycled.

What recommendations would you give to the board?
[70%]

The critical diagram is shown below where 1 - r units of raw material together with r units of recycled material produce
1 - r units of product



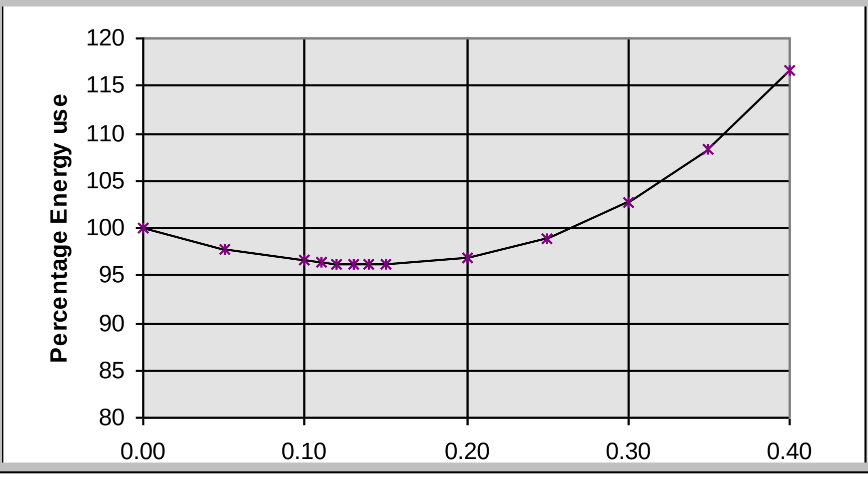
Energy required in process is given by formula as a function of proportion recycled (r). Hence relationship of energy consumption can be found from equation. Solution is best done in tabular form to evaluate E. This must be divided by 1 - r to give energy per unti output - in last column

r	1 - r	$187.5*(1-r)^2$	E	e/(1 - r)
0.00	0.40	30.00	100.00	100.00
0.05	0.35	22.97	92.97	97.86
0.10	0.30	16.88	86.88	96.53
0.15	0.25	11.72	81.72	96.14
0.20	0.20	7.50	77.50	96.88
0.25	0.15	4.22	74.22	98.96
0.30	0.10	1.88	71.88	102.68
0.35	0.05	0.47	70.47	108.41
0.40	0.00	0.00	70.00	116.67

By inspection, minimum energy is around 96% and occurs with a recycling of between 10 and 15%. hence rather than reduce waste the is evidence that inscreased rtecycling should improve energy efficiency. Refine analysis

0.10	0.30	16.88	86.88	96.53
0.11	0.29	15.77	85.77	96.37
0.12	0.28	14.70	84.70	96.25
0.13	0.27	13.67	83.67	96.17
0.14	0.26	12.68	82.68	96.13
0.15	0.25	11.72	81.72	96.14

Hence the optimum recycling is 14% - see also graph. Minimum could be evaluated graphically.



5. What is meant by the term ‘U-value’ and how is it used to assess the heat loss from a building?

[10%]

How would you estimate the U-value of a structural component of a building composed of multiple layers of materials with different properties?

[20%]

Figure 1 shows a method whereby the thermal performance of solid walls may be improved. Estimate the U-value both without and with the fibre-glass insulation layer. Does the latter U-value conform to the current Building Regulation value of 0.45 W m-2 oC-1?

[70%]

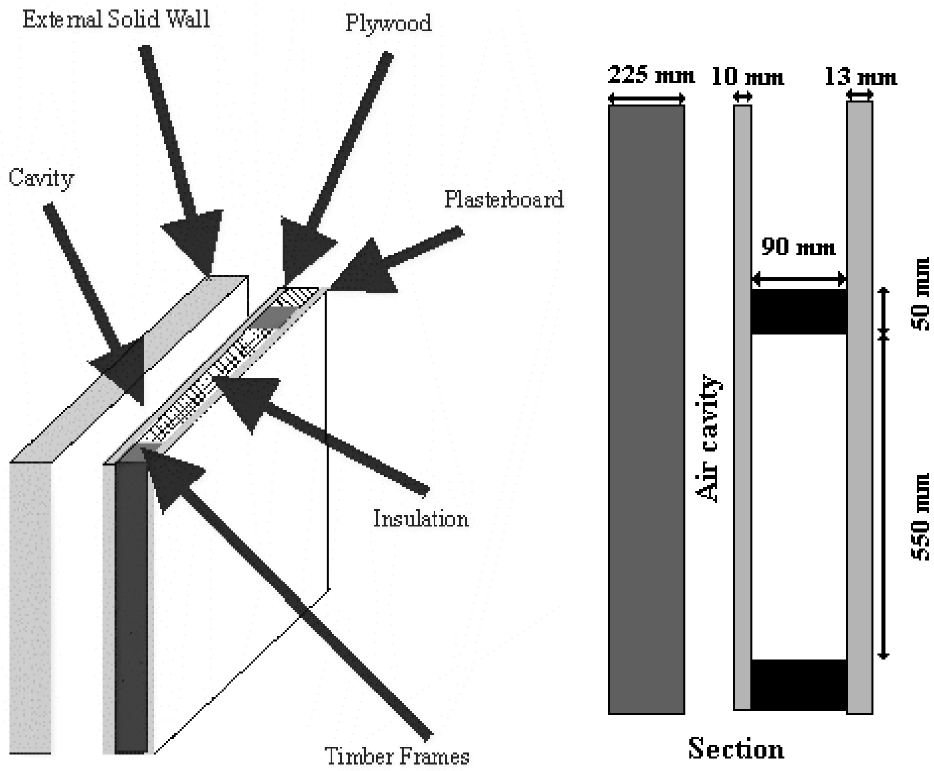
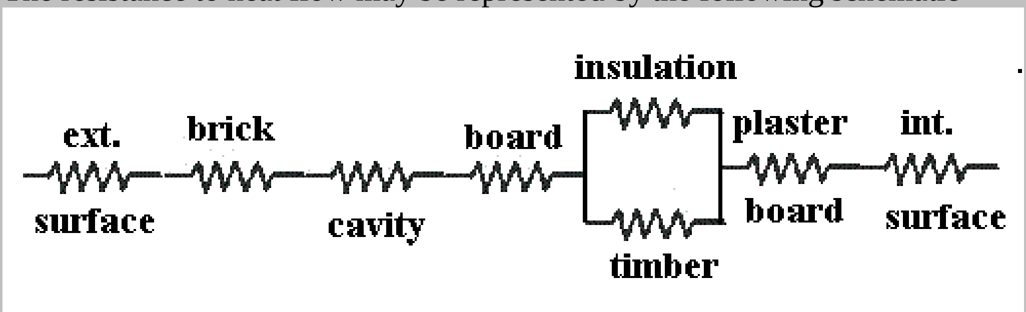


Figure 1: Section through composite wall

The resistance to heat flow may be represented by the following schematic



also $\mathbf{r} = \frac{\ell}{\mathbf{kA}} = \frac{\ell}{\mathbf{k}}$ since area A is unity

The effective resistance $\mathbf{R_{eff}}$ of the parallel paths of insulation and timber is given by

$$\frac{1}{R_{effective}} = \frac{1}{r_{timber}} + \frac{1}{r_{insulation}} = \frac{0.14}{0.09}\cdot\frac{1}{12} + \frac{0.04}{0.09}\cdot\frac{11}{12} = 0.537$$

Here the 1/12 and 11/12 reflect the proportional widths of the timber and insulation (i.e. 50 mm of to,mber every 600 mm (1/12) to 550 mm of insulation)

hence $\mathbf{R_{eff}}$ = 1/ 0.537 = **1.862 W m^{-2} ^{o}C^{-1}**

The total resistance ot heat flow $= r_{ext} + r_{brick} + r_{cavity} + r_{board} + r_{eff} + r_{plasterboard} + r_{int}$

component	thickness	conductivity	resistance
external surface resistance			0.06
brick	0.225	1.0	0.225
cavity			0.18
board	0.01	0.124	0.081
effective insulation			1.862
plasterboard	0.013	0.16	0.081
internal surface resitance			0.123
		Total	[illegible]

SECTION C (50%)

6. Describe how a small scale Combined Heat and Power (CHP) plant differs from one based on a centralised power station. What difficulties are likely to be encountered in matching the size of such a CHP unit with the local requirements, and how should these be resolved so as to be most cost effective? [30%]

It is planned to install three 1 MW CHP units to partly supply energy needs at a University. The units will also produce 1.4MWth of useful heat. The demand for heat is 500 kW ^{o}C^{-1} and the neutral (balance) temperature in the University is 15.5 ^{o}C. Currently the heat is supplied by gas fired boilers running at an efficiency of 80% while the CHP units are expected to reach an overall efficiency of 88.3%. Data relating to the mean external temperature and the mean electricity demand in each month are shown in Table 1. In the scheme there is no provision to dump surplus heat. The mean hot water requirement is 2MW.

If the primary energy ratios for gas and electricity are 1.06 and 2.90 respectively, estimate

a) the proportions of the electricity and heat demand likely to be provided by the CHP units.
b) the overall proportional saving in primary energy from using the CHP units.

[70 %]

[You may assume that all months have an equal number of days]

Table 1:

Month	Mean Temperature (^oC)	mean Electricity Demand (kW)
1	1.9	3900
2	4.5	3600
3	9	3400
4	12	3000
5	14	2800
6	16	2600
7	17	2400
8	16	2400
9	13	2600
10	11	3215
11	8.8	3500
12	4.1	3900

Solution is best done in tabular form.

Column 3 = (15.5 - column 2)* 500 - [500 is heat loss rate]

Column 4 is column 3 + hot water requirement

column 5 is given data

Column 6 is column 5 * 1.4 and is heat that can be supplied from CHP, however, if the electricity is greater than the rating of the units, then the heat output will be 1.4 * 3000 = 4200

Column 7 is the useful heat that CHP can supply. If the potential CHP heat is greater than demand, then only the demand will be useful

Column 8 is heat to be supplied by Supplementary Boiler and equals column 4 - column 6

As there is no surplus heat dump, the electricity generated will be limited if the CHP heat available exceeds the heat required. Thus the electricity that can be generated will be 3000 kW if the CHP heat is less than total heat demand or the total heat demand divided by 1.4. The results are shown in column 9. The values with *** indicate where electricity output is restricted.

Column 10 computes the supplementary electricity required. The peak import is in the summer, even though the demand for electricity is lower than in winter.

Month		Space heating Demand (kW)	Total Heat Demand (kW)	Electricity (kW)	CHP heat (kW)	useful CHP heat (kW)	Supplementary boiler heat (kW)	Actual Electricity that can be generated (kW)	Supplementary Electricity needed (kW)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
1	1.9	6800	8800	3900	4200	4200	4600	3000	900
2	4.5	5500	7500	3600	4200	4200	3300	3000	600
3	9	3250	5250	3400	4200	4200	1050	3000	400
4	12	1750	3750	3000	4200	3750		2679***	321
5	14	750	2750	2800	3920	2750		1964***	836
6	16		2000	2600	3640	2000		1429***	1171
7	17		2000	2400	3360	2000		1429***	971
8	16		2000	2400	3360	2000		1429***	971
9	13	1250	3250	2600	3640	3250		2321***	279
10	11	2250	4250	3100	4200	4200	50	3000	100
11	8.8	3350	5350	3400	4200	4200	1150	3000	400
12	4.1	5700	7700	3900	4200	4200	3500	3000	900
		Total	54600	37100	47320	40950	13650	29250	7850
			GWh	GWh	GWh	GWh	GWh	GWh	GWh
			39.31	26.71	34.07	29.48	9.83	21.06	5.65

To complete the last part of the numeric section, the values in columns 4 - 9 should be summed and converted into GWH by multiplying by 30 x 24 [number of days in each month is assumed at 30]

(a)

Situation before CHP

	Total Demand	Efficiency	PER	Primary Energy
	GWh			GWh
heating	39.31	0.8	1.06	52.09
electricity	26.87	1	2.9	77.91
total				**130.00**

Situation after CHP

	Total Demand	Efficiency	PER	Primary Energy
	GWh			GWh
CHP heating	29.48			
CHP electricity	26.87			
Total CHP	56.35	0.883	1.06	67.65
supplementary heating	9.83	0.8	1.06	13.02
supplementary electricity	5.81	1	2.9	16.84
				97.51

The primary energy is derived from the Total demand / efficiency and multiplied by PER

7. You have been selected for interview for the position of Energy Manager and, along with other candidates, you have been asked to prepare a presentation on your ideas on Energy Management and also provide background notes to the Interview Panel.

You should outline on the left-hand page the form your overheads will take, while on the right-hand page should appear the associated notes to be issued.

8. Describe how a heat pump works. Review the different generic types of heat pump available giving advantages and disadvantages of each type.

Give examples of situations where heat pumps can be used effectively both in direct heating and in heat recovery systems.

UNIVERSITY OF EAST ANGLIA

School of Environmental Sciences

Spring Semester Examination 2002

ENERGY CONSERVATION

ENV-2D02

Time allowed: Two hours

Answer **THREE** questions, **ONE** question from **EACH** section.
Questions in Section **A** carry **TWICE** the number of marks as those in Sections **B** or **C**.

Answer **EACH** question in a **SEPARATE** answer book.

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This includes Model Answers for many of the questions

SECTION A (50%)

1.

Write a review paper decribing both the successful and unsuccesful energy conservation schemes considered by the University of East Anglia in the last 25 years.

Question 1

There are six major projects of an energy conservation nature which have been considered by UEA in the last 25 years. **A good account of three of the schemes below could achieve a first class mark**, provided that at least two schemes were from the 1990s. Diagrams should be included in all the 1990's schemes.

- **heat pump scheme – dating from 1981**. This explored the possibility of using heat pumps for heating residences during the summer period. Though the UEA boilers were 83% efficient in winter, in summer they fall to 40% or less and are thus inefficient. Coupled with the increasing cost of oil at time, it became attractive to consider other alternatives. Further, a prolonged shut down of the boiler house would permit better maintenance and improve winter time efficiency. For three months, no heating is required in teaching wall, and domestic hot water would have been provided by localised boilers as would similar water for the residences. The initial costings of the scheme were show to be very pessimistic and savings of between £45000 and £90000 per annum would have been achieved. However, the scheme was later considered by a professor of economics who imposed unrealistic discount rates of 20%, and assumed that space heating would be require on all but 10 days of the summer period – something which it is difficult to justify in the British climate. On his analysis, and with these distorted assumptions the viability of the project was marginal and so the scheme was not pursued.
- **small boiler scheme – dating from 1983.** The existing UEA boilers have a rated output of 8MW each, and can achieve an efficiency of around 83%+ on full load, however, despite having twin burners, the efficiency drops rapidly as the load decreases, and often in summer, the efficiency was 30% or less. A further problem arose from the boilers needing to operate at a flow and return temperatures of about 115^{o}C and 105^{o}C respectively meaning that the mains losses were considerable amounting to 300 kW or more. A boiler with 4MW maximum output and modulation facilities was installed in 1983. The prime aim was to use this boiler in summer when the demand was low and the actual efficiency could be more closely matched to the design output, partly because the demand was more closely matched, and partly because the effective operating temperature could be adjusted to a lower value in summer leading to lower mains losses. This scheme proved to be very cost effective and also saved energy.
- **gas conversion scheme – dating from 1987.** This was more a case of economics because of the differential price of gas and oil, but some marginal improvement in efficiency was achieved.
- **Student Residences: Constable Terrace/Nelson Court** – see article on WEB
- **Elizabeth Fry/Medical School/ZICER** – see article on WEB
- **CHP Scheme - see article on WEB**
- **Absorption Chilling**

2.

Describe the different gas and electricity tariff structures now available in the domestic sector in the UK explaining the type of tariff more attractive to the different types of consumer.

[30%]

You work for a firm providing independent advice to consumers on the range of electricity tarriffs available. You are approached by a consumer who has energy consumption profiles as shown in Table 4. What advice would you give to the consumer regarding the choice of suppliers based on the tariff information supplied in Table 5.

[70%]

Table 4

kWh

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Present Supplier
electricity	1050	900	1000	1050	Company A
gas	7000	5000	3000	5000	Company A

Table 5

Company	Fuel		standing charge £ per quarter	charge for first units (p)	break point	charge for remaining units (p)	cash incentives
A	electricity		10	6.2			annual discount of £16 if both fuels are supplied.
	gas		10	1.2			
B	electricity		0	7.5	700	7	A once off £5 discount per fuel for New Consumers switching to Company B
	gas		0	1.8	1500	1.2	
	electricty	both fuels	0	7.4	700	6.9	
	gas		0	1.8	1250	1.2	
C	electricity		5	6.8	700	6.3	
	gas		5	1.4	1500	1.3	
	electricty	both fuels	5	6.7	700	6.2	
	gas		5	1.4	1500	1.2	
D	gas		5	1.4	4000	0.7	

Question 2.

As there is no break point for Company A tariffs, the conumsption data can be aggregated on an annual basis. Similarly for consumer A, both electricity and gas consumption level are above the break points for all tariffs of Companies B & C, and annual aggregation of data is thus permissible again. For Company D, the break Point is above the consumption in the third quarter and thus analysis for this company must be made on a quarterly basis

For Companies A, B, and C

annual consumption electricity: = 1050 + 900 + 1000 + 1050 = 4000 kWh
gas = 7000 + 3000 + 5000 + 5000 = 20000 kWh

both fuels are supplied by **Company A** so present annual costs are:-

4 x standing charge = no of units x unit charge
electricity = 4 x 10 + 4000 x 6.2/100 = £288
gas = 4 x 10 + 20000 x 1.2/1000 = £280
so total present charge will be £288 + £280 = £568, but with the "dual fuel" discount, the annual charge will be 568 – 16 = **£552**

For company B
annual charge is 4 x standing charge + 4 x break point units x unit charge for first units
+ (no of units above 4 x break point units) x remaining unit charge
electricity: 4 x 0 + 4 x 700 x 7.5/100 + (4000 – 4 x 700) x 7.0/100 = £294
similarly for gas: 4 x 0 + 4 x 1500 x 1.8/100 + (20000 – 4 x 1500) x 1.2/100 = £276
using dual fuel tariffs
the prices are 4 x 0 + 4 x 700 x 7.4/100 + (4000 – 4 x 700) x 6.9.0/100 = £290
4 x 0 + 4 x 1250 x 1.8/100 + (20000 – 4 x 1250) x 1.2/100 = £270
Total cost is both fuels supplied = **£560**

For company C

analysis is similar to that for Company B except that standing charge is non-zero

electricity 4 x 5 + 4 x 700 x 6.8/100 + (4000 – 4 x 700) x 6.3/100 = £286
gas 4 x 5 + 4 x 1500 x 1.4/100 + (20000 – 4 x 1500) x 1.3/100 = £286

For dual fueld option

electricity 4 x 5 + 4 x 700 x 6.7/100 + (4000 – 4 x 700) x 6.2/100 = £282
gas 4 x 5 + 4 x 1500 x 1.4/100 + (20000 – 4 x 1500) x 1.2/100 = £272

Total cost is both fuels supplied = **£554**

For Company D

1st Quarter £5 + 4000 **1.4/100** + **(7000-3000)**0.7/100 = £82.25
2nd Quarter £5 + 4000 **1.4/100** + **(7000-3000)**0.7/100 = £68.25
3rd Quarter £5 + 4000 **1.4/100** + **(7000-3000)**0.7/100 = £47.25
4th Quarter £5 + 4000 **1.4/100** + **(7000-3000)**0.7/100 = £68.25
TOTAL = **£266**

Comparinmg Option of changing supply of both fuels to another company.
Present annual cost is £552 with Company A
With Company B cost would be £560 - but with a 2 x £5 once of discount would be £550 in first year
With Company C cost would be £554

So no incentive to change to Company C

Cheapest Single Fuel Annual Cost for Electricity is Company C at £286
[once off discount for Company B still makes this most expensive]
Cheapest Single Fuel annual cost for gas is Company D at £265

Choosing electricity from Company C and gas from Company D would give an annual cost of £551

Advice to consumer

- At the level of consumption, there is very little to choose between the Companies, although switching to Company C for electricity and Company D for gas would save £1 per year.
- Switching both fuels to Company B would save £2 in first year, but be more expensive thereafter. To optimise saving the consumer should switch to Company B for one year and then split to have supply of electricty From Company C and gas from Company D thereafter.

- Advice should also contain the following information that should consumption of gas rise, then Company D becomes increasingly attractive because of the very low final unit charge.
- Similarly electricity from Company A would become more attractive with a rise in electricity consumption.

===

3.

To what extent does the Standard Assessment Procedure (SAP) Rating help or hinder the promotion of energy conservation measures in buildings? How does this procedure compare with other methods?

Question 3.

Points which should be included for a good answer

basic description

- SAP rating first became part of Building Regulations in 1994, and a revised version is due to come into force on 1st April 2002
- though original basis of rating is overall energy use, final calculation involves cost of energy and this can distort the SAP significantly

Advantages of the SAP rating system.

- attempts to include efficiency of heating appliances as well as insulation values of components
- incorporates provision for incidental gains
- includes option for solar water heating
- specifies U-values for structural components, but relaxes values if SAP rating is above 60
- Building regulation associated with SAP now make double glazing essential for all domestic buildings.
- provides a scale by which to compare performance of houses and attempts compensate for house size. Higher rating is best with values ranging from 0 upwards. Values over about 82 (depending on actual house size) are considered to be good and automatically satisfy Building Regulations.
- rating is published on new houses, and will also be required on sales of older houses.

Disadvantages of SAP Rating System which hinder promotion of further energy conservation

- still allows trade off – i.e. provided a good SAP rating is achieved, then insulation performance of one or more components can be relaxed – leading to a minimum compliance rather than promoting conservation.
- theoretically, because of formulation of SAP final calculation it is possible to achieve a SAP rating in excess of 100 (in fact 115 can be achieved). However, practically with current technology it is not easy to get above 100, and thus SAP rating system promotes the current best technology rather than what might be achieved in future. A better system would have a theoretical maximum of 100. The new (SAP 2001) has a scale extending to 120.
- the final calculation is heavily biased towards cost of fuel, and anomalies arise – e.g. propane from cylinders rather than mains gas has a poor rating (and worse than electricity in many cases) even though energetically it is a much more efficient energy source contributing much less in way of greenhouse emissions.
- scheme only is appropriate for houses – other buildings such as residential homes, commercial buildings are exempt and have relaxed rules regarding insulation.
- no specification is given for ventilation requirements even though these can be significant heat losses. However guidance is given on how to compute ventilation losses.
- overall method of calculation is much more complex than previous Building Regulation scheme.
- SAP rating is based on a theoretical performance of a building and assumes insulation (e.g. in a loft) is fully in place and not tampered with.
- relates incidental gains according to floor area, whereas actual incidental gains are a function of occupancy. Thus SAP rating may not give indication of actual energy consumption as incidental gains can vary significantly according to occupancy. However, as a benchmark by which to compare different houses, , it is probably the best that can be achieved.

    - **Elemental Method**
      This specifies a minimum U-value for all fabric components, and in the 2000 Regulations, coming into force on April 1st 2002, these are quite strict requiring, for example either triple glazing or double glazing with ultra-low emissivity. Conventional double glazing will not meet the standard, nor will traditional cavity filled walls. This is this much more strict than a method based on SAP Rating, but does not make allowance (except in a very crude way) for appliance efficiency.
    - **Target U-Value**
      This allows some freedom from the Elemental Approach by specifying an aggregate weighted U-value which must not be exceeded. This allows some freedom of design as greater glazing areas can be compensated by improvements elsewhere. Overall this is a more sensible approach than the SAP rating scheme , but it does not make allowance (except in a very crude way) for appliance efficiency.

- **Carbon Index (as of 1st April 2002)**
  This follows the SAP procedure up to the point where it includes economic issues, and instead computes CO_2 emissions which are then translated into an Index. If a dwelling exceeds 8.0 on this Index, then it will automatically satisfy the requirements. This system has the advantages of the SAP Rating by incorporating hot water use etc, but does not suffer from the inconsistencies arising by incorporating economic factors of the SAP Rating Method.

From April 2002, the SAP Rating will still be required, but by itself will not comply with the new Regulations.

There are three other methods:
Other points which deserve credit and should be included in a good answer - actual values of U-values permitted, and evidence that section L1 of the 2000 Building Regulations and also SAP 2001 have indeed been read.

SECTION B (25%)

4.

Describe one method involving temperature correction which will allow actual and projected energy consumption data for space heating to be compared.

[30%]

A detached house 8m x 7m in plan area and 6m high with 20 sqm of window is heated by a gas condensing boiler whose efficiency as defined in the SEDBUK (seasonal Efficiency of Domestic Boilers in the UK) database is 89.33%. Using the U-value data given in Table 2 and the actual measurements of the heat requirements at different temperatures in Table 3, estimate the ventilation rate in the house if the specific heat of air is 1300 J m^{-3} $^{o}C^{-1}$.

[70%]

Table 2

Component	U – Value
External Walls	0.40
Windows	2.80
Roof	0.15
Floor	0.60

Table 3

External Temperature (^{o}C)	Heat Requirement (W)
0	5495
2	4915
4	4335
6	3755
8	3175
10	2595

Question 4.

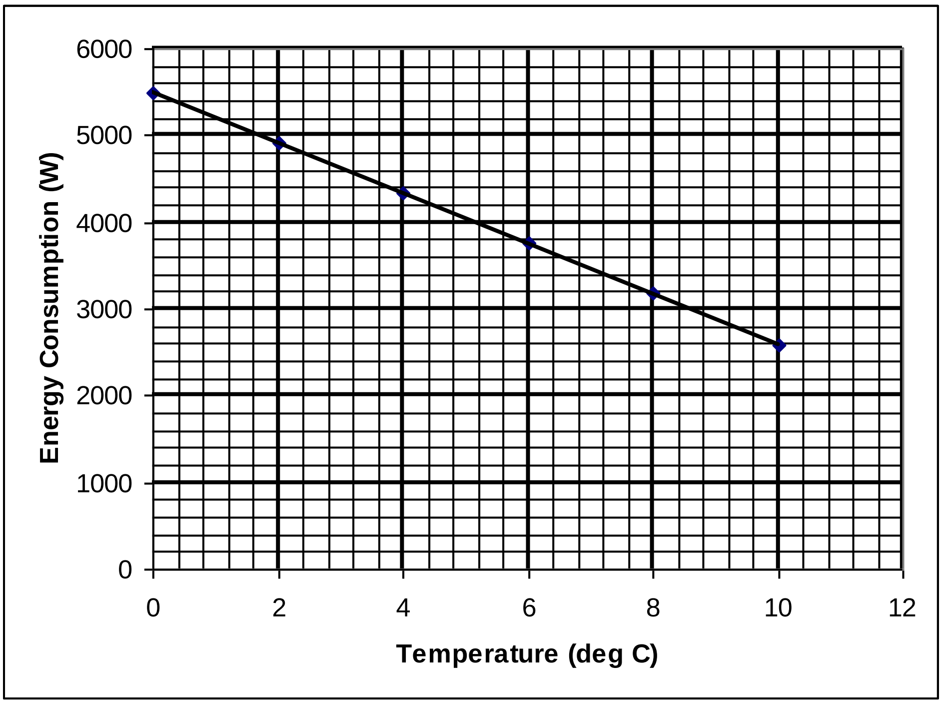
Numeric Part

data: - length = 8 m; width = 7 m; height = 6m
calculation is most efficiently done in tabular form: heat loss rate = Area x U-value

	calculation of area	area	U-value	heat loss rate (W $^oC^{-1}$)
windows		20	2.8	56
walls	=(2 x 8 + 2 x 7) x 6 – area of windows	160	0.4	64
floor	= 8 x 7	56	0.6	33.6
roof	= 8 x 7	56	0.15	8.4
		TOTAL		162

W per sqm per de

but H + V x S x ach = T or ach = (T – H)/VS * 3600
where H is heat loss rate through fabric as defined above
V is volume
S is the Specific heat of Air
ach is the air changre rate
T is the Total heat loss rate from fabric and ventilation.



gradient of line is total heat loss rate = 290 W$^oC^{-1}$.
allowing for boiler efficiency, the total heat loss rate = 290 x 0.8933 = 259.06 W$^oC^{-1}$.
thus for equation air change rate = (259.06 – 162)/(8 x 7 x 6 x 1300)*3600 = 0.7999
= **0.8** air changes perhour
==

5.

During the last 4 months of 2001 a new centralised cooling water system was installed in the School of Environmental Sciences which will provide cooling water at temperatures ranging from 5°C in winter to 15°C in summer. A new X-Ray Diffractometer was delivered at the end of 2001 which which required cooling water at a flow rate of between 3.6 and 4.4 litres per minute and within a temperature range of 16°C and 24°C. Below 16°C the machine malfunctions. As a temporary solution an electrical heater was provided to heat the inlet cooling water. It was also noted that in an adjoining room a scanning electron microscope (SEM) exhausted 3 kW of heat to a parallel circuit on the cooling circuit.

Devise a scheme to utilise the waste heat from the SEM and estimate the saving in energy from such a scheme..

[30% of the marks will be awarded for a description of the proposed scheme and the remainder of the marks for checking that the scheme is viable].

Question 5

There are two critical conditions to consider:-

1. winter minimum temperature of cooling water of 5°C at inlet which will specify minimu heat requirement, and
2. summer maximum inlet temperature to check that it does no exceed 24°C.

In winter, water temperatur must be raised by a minimum of 16 – 5 = 11 °C.
using a mean flow rate of 4 litres per minute, the energy required will be

4	x	4.1868	x	11	=	184.2 kJ per minute or 3.07 kW
flow rate		specific heat		temperature		

Thus with 3 kW from SEM and cooling water connected in series with the SEM this is just not sufficient, so drop flow rate to say 3.8 and the requirement is 2.91 kW so inlet temperture to XRD will be slightly above required minimum of 16°C.

Now check summer time minimum requirement t raise temp by 1 °C, the energy requirement also at a flow rate of 3.8 litres per minute is 0.265 kW.
So heating energy required if waste from SEM is not used is (2.91 + 0.265)/2 x 8760
= **13906.5 kWh or 50 GJ** per annum, and this will thus be the saving in energy.

However, 3 kW is available in summer so check inlet temperature in summer conditions.

temperature rise = 3/(3.8 /60 x 4.1868) = 11.31 °C.

So inlet temperature will be 16 +11.31 = 27.31 which is too high.

Solution adopt a hybrid scheme in which in winter the cooling water for the XRD is entirely in series with the SEM and three way mixing valves to allow a partially parallel/ partially series sequence in summer with 50% of water derived from SEM and 50% directly from cooling water. In this case the temperature rise will be half that computed above and thus will be within specification.

==

SECTION C (25%)

6.

The use of electricity in many applications is wasteful and yet its consumption is likely to rise in a countrry which actively promotes energy conservation and environmental measures. Explain this paradox.

7.

Describe how a combined cycle gas turbine differs from conventional turbines used in the generation of electricity. What advantages and disadvantages are there with these types of turbines?

8.

What information can be obtained from an Energy Balance Table?

[30%]

Using Table 1 as an example prepare guidance notes to explain how the key figures in an Energy Balance Table arise.

You should attach an annotated copy of Table 1 to your answer.

[70%]

A suggested answer to this question is shown after the Table on the next page.

Aggregate Energy Balance 2000 - derived from Table 1.1 of DUKES (2001) PJ

	Coal	Manufactured fuel (1)	Primary oils	Petroleum products	Natural gas (2)	Renewable & waste (3)	Primary electricity	Electricity	Total
Energy Supply									
Indigenous production	819	-	5790	-	4533	104	844	-	12089
Imports	659	15	2485	650	94	-	-	52	3953
Exports	-21	-13	-4253	-937	-527	-	-	-1	-5752
Marine bunkers	-	-	-	-92	-	-	-	-	-92
Stock change (4)	140	-10	50	-16	-34	-	-	-	130
Primary supply	1596	-8	4071	-396	4066	104	844	51	10328
Statistical difference (5)	2	-8	23	40	47	-	-	4	108
Primary demand	1594	0	4049	-436	4019	104	844	47	**10220**
Transfers	-	5	-8	13	-2	-	-22	22	8
Energy Conversion	-1484	131	-4025	3903	-1126	-72	-822	1318	**-2177**
Electricity Generation	-1197	-38	-	-45	-1126	-72	-822	1318	**-1981**
Major Power Stations	-1162	-	-	-18	-1022	-9	-822	1205	-1827
Autogenerators	-35	-38	-	-27	-104	-62	-	113	-154
Refineries	-	-	-4025	3956	-	0	-	-	-69
Coke Manufacture	-257	236	-	-	-	-	-	-	-21
Blast Furnaces	-14	-83	-	-8	-	-	-	-	-106
Patent Fuels	-16	17	-	-	-	-	-	-	1
Energy Industry Use TOTALS	0	47	15	230	290	-	-	96	**679**
Electricty Generation	-	-	-	-	-	-	-	59	59
Oil and Gas Extraction	-	-	15	-	236	-	-	2	253
Refineries	-	-	-	223	19	-	-	18	261
Coal Extraction	0	-	-	-	1	-	-	5	6
Coke Manufacture	-	24	-	-	0	-	-	-	24
Blast Furnaces	-	22	-	5	3	-	-	3	33
Patent Fuels	-	1	-	-	-	-	-	-	1
Pumped Storage	-	-	-	-	-	-	-	3	3
Other	-	-	-	2	31	-	-	7	39
Losses	-	7	-	-	45	-	-	107	**158**
Energy Available for Consumption	109	82	-	3249	2557	32	-	1184	**7214**
INDUSTRY	39	62	-	267	722	15	-	409	**1515**
Unclassified	-	11	-	97	0	15	-	-	124
Iron and Steel	0	47	-	6	77	-	-	36	165
Non-ferrous metals	3	5	-	2	21	-	-	21	52
Mineral Products	8	-	-	11	55	-	-	27	100
Chemicals	12	-	-	16	206	-	-	82	316
Mechanical Engineer	0	-	-	9	39	-	-	33	81
Electrical Engineering	0	-	-	2	15	-	-	22	40
Vehicles	2	-	-	6	40	-	-	20	69
Food and Beverages	6	-	-	13	115	-	-	45	179
Textiles, leather	2	-	-	6	27	-	-	14	49
Paper, printing	3	-	-	3	63	-	-	41	110
Other	4	-	-	76	56	-	-	63	199
Construction	-	-	-	20	8	-	-	6	33
Transport	-	-	-	2280	-	-	-	32	**2311**
Air	-	-	-	497	-	-	-	-	497
Rail	-	-	-	20	-	-	-	-	20
Road	-	-	-	1720	-	-	-	-	1720
Inland Navigation	-	-	-	43	-	-	-	-	43
Other	70	20	-	237	1788	17	-	744	**2875**
Domestic	61	20	-	136	1332	10	-	403	1961
Public administration	8	-	-	48	196	3	-	82	337
Commercial	-	-	-	21	157	-	-	246	423
Agriculture	0	-	-	27	5	3	-	14	49
Miscellaneous	0	-	-	6	98	1	-	-	105
Final Consumption Energy only	**109**	**82**	**-**	**2783**	**2511**	**32**	**-**	**1184**	**6702**
Non-Energy Use	-	-	-	466	47	-	-	-	**513**

Calorific Value used 1 tonne of oil equivalent = 41.87 GJ

Question 8: ENERGY BALANCE TABLES

Supply

- **Line A** is total supply allowing for extraction, imports, exports and stock changes. The Statistical Differences refer to the differences between the Primary Supply and Primary Demand. the reason for the differences are many fold, but include rounding errors from the many suppliers, differences in accounting periods etc.

The figure of **10220 PJ**, or more correctly **10..22 EJ,** is the annual UK consumption of Energy and represents an increase 4% from **9.75 EJ** since 1991. A small amount of energy in the form of oil/gas is use as chemical feed stocks as shown in line K, and thus the true Energy use in the UK is **10.220 - 0.513 = 9.707EJ** – a 1.29% rise since 1998..

- **Line B** refers to transfer and arises partly because of the aggregation of data to simplify the table. It mostly represents reclassification between the raw suppliers and the energy conversion industries. For instance some gas under pressure at the well head would be in liquid form, but at lower pressure at use would be as gas. Equally, some gas is pressurised before pumping and is received in liquid form.
- **Line C** indicates the energy consumed (-ve numbers) or produced in (+ve numbers) in the Energy Conversion Industries. Thus of a Primary Demand of **1594 PJ** of coal **1484 PJ** were directly used in producing secondary fuels such as electricity, coke etc. Similarly **4025 PJ** of crude oil was converted in refineries while **3903 PJ** of petroleum products were produced. **1126 PJ** of gas and **72PJ** of renewables (mostly as waste/biomass) were used in conversions. Finally, the whole of the residual primary electricity **822 PJ** (nuclear) is converted at this stage and was used in conversion. The **2177 PJ** in the final column is significant as this, being negative represents the losses incurred in converting energy.
- The lines shown by a * beneath line C show the distribution of each fuel for conversion. Thus of the **1484 PJ** of coal, **1197 PJ** went to the Power Stations, while **257 PJ** went to coke manufacture for the Iron and Steel Industry. Equality all the crude oil went to the refineries, while all the natural gas used in conversion went to the Power Stations. The figure of **1126 PJ** represent an increase from just 49PJ in 1991 i.e. a 23 fold times increase in just 9 years and reflects the so-called dash for gas. Row C is in fact the sum of the values in the * rows.

  The line "Major Power Producers" refers not only to the established names such as PowerGen and National Power, but also the Independents such as Lakeland Power etc. The Autogenerators refer to generators who produce electricity for their own use - such as UEA.

- The previous section refers to the actual energy use in the conversion process - e.g. the thermodynamic conversion in the case of electricity. It does not reflect the energy use by the supply industries. Row D shows the amounts of energy used in these industries. For instance electricity is used in power station to drive pumps, grind coal, while electricity is also used in coal mine to cut coal. The aggregate amounts of each fuel used by the energy supply industries is shown in **Row D**.

  Thus electricity generation consumes **59 PJ** in station use, while the refineries **use 15 PJ** of crude oil, **236 PJ** of gas and **2 PJ** of electricity.

- **Line E** refers to the transmission losses between the power station and the consumer in the case of electricity or the use of gas and leakages in the case of gas distribution.
- **Line F** is the net amount of energy available to the consumer.

  Line F = Line A + Line B + Line C - Line D - Line E

  This represents the main energy balance

Demand

- **Line G** shows the total amount of each fuel used by industry for each fuel type, while below that line the figures are disaggregated into the separate industrial sectors.
- **Line H** relates to transport, and once again, this section is also disaggregated.
- **Line I** shows the aggregated Delivered Energy to all other sectors with a split between the different sectors in the following Rows
- **Line J** shows the total amount of energy actually delivered for use while, as indicated above, **Line K** represents the Non-Energy uses.

Aggregate Energy Balance 2000 - derived from Table 1.1 of DUKES (2001) PJ

	Coal	Manufactured fuel (1)	Primary oils	Petroleum products	Natural gas (2)	Renewable & waste (3)	Primary electricity	Electricity	Total	
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Indigenous production	819	-	5790	-	4533	104	844	-	12089	
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Statistical difference (5)	2	-8	23	40	47	-	-	4	108	
Primary demand	1594	0	4049	-436	4019	104	844	47	**10220**	**A**
Transfers	-	5	-8	13	-2	-	-22	22	8	**B**
Energy Conversion	-1484	131	-4025	3903	-1126	-72	-822	1318	**-2177**	**C**
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Refineries	-	-	-4025	3956	-	0	-	-	-69	*
Coke Manufacture	-257	236	-	-	-	-	-	-	-21	*
Blast Furnaces	-14	-83	-	-8	-	-	-	-	-106	*
Patent Fuels	-16	17	-	-	-	-	-	-	1	*
Energy Industry Use TOTALS	0	47	15	230	290	-	-	96	**679**	**D**
Electricty Generation	-	-	-	-	-	-	-	59	59	+
Oil and Gas Extraction	-	-	15	-	236	-	-	2	253	+
Refineries	-	-	-	223	19	-	-	18	261	+
Coal Extraction	0	-	-	-	1	-	-	5	6	+
Coke Manufacture	-	24	-	-	0	-	-	-	24	+
Blast Furnaces	-	22	-	5	3	-	-	3	33	+
Patent Fuels	-	1	-	-	-	-	-	-	1	+
Pumped Storage	-	-	-	-	-	-	-	3	3	+
Other	-	-	-	2	31	-	-	7	39	+
Losses	-	7	-	-	45	-	-	107	**158**	**E**
Energy Available for Consumption	109	82	-	3249	2557	32	-	1184	**7214**	**F**
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Non-ferrous metals	3	5	-	2	21	-	-	21	52	
Mineral Products	8	-	-	11	55	-	-	27	100	
Chemicals	12	-	-	16	206	-	-	82	316	
Mechanical Engineer	0	-	-	9	39	-	-	33	81	
Electrical Engineering	0	-	-	2	15	-	-	22	40	
Vehicles	2	-	-	6	40	-	-	20	69	
Food and Beverages	6	-	-	13	115	-	-	45	179	
Textiles, leather	2	-	-	6	27	-	-	14	49	
Paper, printing	3	-	-	3	63	-	-	41	110	
Other	4	-	-	76	56	-	-	63	199	
Construction	-	-	-	20	8	-	-	6	33	
Transport	-	-	-	2280	-	-	-	32	**2311**	**H**
Air	-	-	-	497	-	-	-	-	497	
Rail	-	-	-	20	-	-	-	-	20	
Road	-	-	-	1720	-	-	-	-	1720	
Inland Navigation	-	-	-	43	-	-	-	-	43	
Other	70	20	-	237	1788	17	-	744	**2875**	**I**
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Public administration	8	-	-	48	196	3	-	82	337	
Commercial	-	-	-	21	157	-	-	246	423	
Agriculture	0	-	-	27	5	3	-	14	49	
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Final Consumption Energy only	**109**	**82**	**-**	**2783**	**2511**	**32**	**-**	**1184**	**6702**	**J**
Non-Energy Use	-	-	-	466	47	-	-	-	**513**	**K**

Calorific Value used 41.87 GJ

UNIVERSITY OF EAST ANGLIA

School of Environmental Sciences

Spring Semester Examination 2004

ENV-2D02 ENERGY CONSERVATION

Time allowed : 2 hours

Answer **THREE** Questions, **ONE** from **EACH** SECTION.

Questions in Section C carry **TWICE** the number of marks of those in Sections A or B.

Answer **EACH** Question in a **SEPARATE** BOOK.

Suggested answers follow at the end of the paper.

Section A [25% - 30 minutes]

1. The use of an adsorption chiller with a combined heat and power scheme is sometimes referred to as a "Win-Win combination". Explain what this means in the context of a specific example with which you are familiar. In what circumstances this "Win-Win" situation not be valid?

2. Despite continual attempts by the Government to promote Energy Conservation over the last 20 years, the consumption of electricity has been rising for much of that time at 1.81% per annum. Explain why this is the case. What might be done to curtail demand in the future?.

3. What factors affect an individual's perception of thermal comfort? How are these factors measured or estimated in a given environment?

[50%]

How might thermal comfort be incorporated into an energy management scheme for a large complex of buildings?.

[50%]

Section B [25% - 30 minutes]

4. Describe how a combined cycle gas turbine station differs from a conventional steam turbine.

[20%]

A combined cycle gas turbine station is to be used to supply both electricity and district heating. Data relating to the performance of the different parts of the station are shown in Table 1. Estimate the overall efficiency of the conversion of energy in the station.

Table 2.

Inlet temperature to gas turbine	1139°C
Exhaust temperature from gas turbine	680°C
Inlet temperature to steam turbine	547°C
Condenser temperature	95.5°C
Combustion losses	9.8 %
Isentropic efficiency of both turbines	75 %
Generator efficiencies	95.5 %
Station use of electricity	6 %
Distribution losses on heating mains	12.65 %

[70%]

Summarise the advantages and disadvantages of single shaft as opposed to multiple shaft combined cycle gas turbines.

[10%]

Section B continued

5. Explain how you would deconvolute the published energy statistics to determine the trends in energy efficiency of vehicles over the years. How would you use this information to estimate future energy requirements,

[30%]

Table 2 shows a summary of the Transport Statistics from Table X.YY of the ENV Data Book. Estimate the total energy consumption by light vehicles in 2025 if the fuel efficiency of vehicles improves by 25% on the 2002 figure by that time. Clearly state any assumptions you make.

[70%]

Table 2

Year	Number of Vehicles	Energy Consumption (PJ)	Distance Travelled per vehicle (km)
1965	9659000	547.1	13956
1970	12293000	719.9	14260
1975	14751000	812.1	13904
1980	16233000	957.6	14852
1985	18161000	1030.1	15368
1990	21989000	1252.3	17090
1995	22722000	1174.4	17410
2000	25665000	1185.7	16700
2001	26443000	1160.7	16485
2002	27165000	1149.9	16470

Section C [50% - 1 hour]

6. Critically review the different methods which have been used to demonstrate compliance of Section L of the Building Regulations since 1994. To what extent have these helped or hindered reductions in energy consumption in the Domestic Sector in the UK?

[90%]

What revisions to section L are currently being considered for the next version of the Regulations. Are there any changes you would wish to see ?

[10%]

7. Explain how a heat pump works.

[25%]

Discuss the advantages and disadvantages of the different types of Heat Pump. What factors have limited the exploitation of heat pumps in the UK?

[75%]

Section C continued

8. Describe at least two methods to analyse the consumption of energy required for low temperature heating in a house may be assessed.

[20%]

Explain the differences between the two methods currently used to determine the value of the "Degree-Days" parameter.

[10%]

A house has a heat loss rate of 250 $W^{o}C^{-1}$ and is maintained at a constant temperature of $20^{o}C$ throughout the year. Table 1. Shows the average maximum and minimum temperatures, while the incidental gains amount to 1125W.

Estimate the number of Degree-days using the two different methods, and estimate the likely error in estimating annual consumption if the more common method is used.

[40%]

The house has 25 m^2 of single glazing with an average U-value of 5.0 W $m^{-2 o}C^{-1}$. The windows are replaced by double glazing units with an average U-value of 2.5 W $m^{-2 o}C^{-1}$

If the incidental gains remain the same, estimate the annual saving in energy following these conservation measures

[35%]

Table 1.

Months	Number of days	Maximum Temperature (^{o}C)	Minimum Temperature (^{o}C)
Jan-Feb	59	7.5	0.5
Mar-Apr	61	11	4
May-Jun	61	19	8
Jul-Aug	62	22	12
Sep-Oct	61	15	9
Nov-Dec	61	9	4

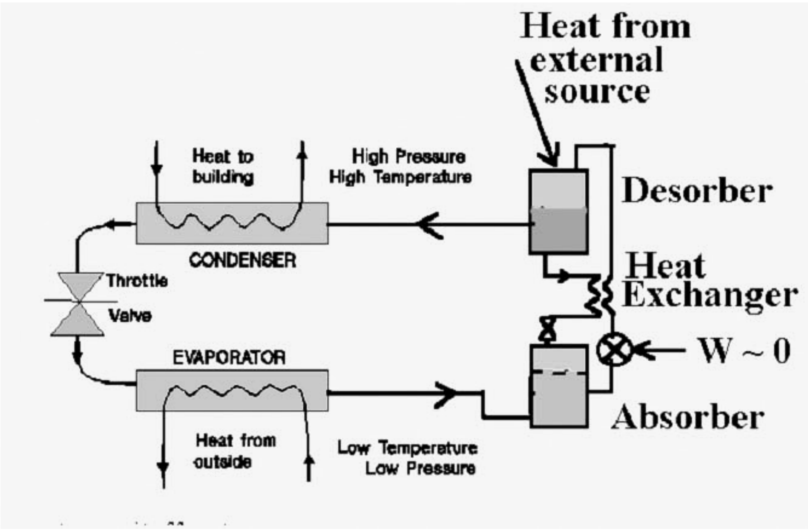
END OF PAPER

Requirements

ENV Data Book
3 sheets of linear x linear graph paper

1. **The use of an adsorption chiller with a combined heat and power scheme is sometimes referred to as a "Win-Win combination". Explain what this means in the context of a specific example with which you are familiar. In what circumstances this "Win-Win" situation not be valid?**

For a good answer it will be necessary to explain that an adsorption chiller is a heat pump which replaces the normal compressor with an additional adsorption – desorption cycle. The purpose of the additional cycle is to provide the required compression and this requires the input of heat and a small amount of electrical energy in a pump. The electrical energy of normal heat pumps is thus considerably reduced. Adsoprtion chillers may use any source of heat, and gas refrigeration equipment is on the market. A good answer will use a diagram such as that shown below to describe the operation.



In the use of combined heat and power equipment, a necessary requirement is the removal of heat whenever electricity is generated. In winter this presents no problems, but in summer, there is usually insufficient heat demand so that the electrical output is limited. In many situations, heat is deliberately dumped to the atmosphere to optimise electrical output. Though this appears environmentally unsound, the fact that CHP units are embedded in the network, means that any electricity generated does not suffer from the normal 8% transmission losses.

In organisations such as the University of East Anglia, there is increasing demand for chilling for scientific equipment, and an adsorption chiller utilising the waste heat output from a CHP unit in summer can provide a so-called "Win-win" situation. Not only can much of the chilling be provided and thereby reduce the electrical demand needed for chilling be reduced, but because there is a ready and reliable heat sink, the amount of electricity which may be generated can be increased.

While chilling may be provided in the summer, it will be inappropriate to run the chiller in winter even though scientific equipment will still require cooling as heat from the units is more effectively used for low temperature space heating for much of the time.

2. **Despite continual attempts by the Government to promote Energy Conservation over the last 20 years, the consumption of electricity has been rising for much of that time at 1.81% per annum. Explain why this is the case. What might be done to curtail demand in the future?.**

Electricity demand between 1973 and 1982 remained almost constant, but since that time it has followed an almost continual growth curve of around 1.81%. Though it appears a paradox, an *economy making a transition to a more energy efficient one will see an initial increase in electrical demand even though overall energy consumption may decline.*

While there have been many initiatives towards energy conservation, the majority in the domestic and commercial sectors have addressed space heating, and electricity plays a relatively small part in the demand for this heating. The only significant strategies to reduce electricity demand have been the introduction of the "Energy Labelling" schemes on White Goods and the more widespread introduction of low energy light bulbs.

Despite these, there has been, and there is likely to be continued growth in electricity demand for several years to come, even when only energy efficient technologies are promoted. There are several examples. In the domestic sector, the current interest in heat pumps will see an increase in electricity demand but a reduction in overall energy demand. Even with a coefficient of performance of three, a heat pump will outperform the best competing technology for individual building heating, and provide an energy saving comparable with CHP. In industry, the use of infra red and inductive heating provide more rapid heating and better control than using conventional heating sources, and reductions in delivered energy requirements approaching 80% are possible far outweighing the normal Primary Energy Ratio of electricity of around 2.8.

The promotion of a hydrogen economy to provide fuel for transportation will require electricity for electrolysis of water, and the same will be true if electric vehicles become more widespread.

All of the above are consistent with a reduction in overall energy demand but all will see an increase in electricity demand.

A separate cause for the increase in demand is the reduced household size and the increase in the number of energy wasteful appliances which have standby functions such as TV's, computer peripherals, mobile phone chargers, micro-waves etc. etc. There is a serious issue of user awareness that needs to be addressed here. The digital revolution and wide-screen television has seen an increase in demand per appliance.

Many of the electrical appliances have a power supply which is wasteful in energy, and development of new appliances in the Entertainment/Computing area could minimise the use of such power supplies. Equally, the use of battery powered standby (the intelligent standby) needs to be promoted further.

A good answer will cover all the above points and give relevant examples and also discuss options for the future

3. What factors affect an individual's perception of thermal comfort? How are these factors measured or estimated in a given environment?

[50%]

How might thermal comfort be incorporated into an energy management scheme for a large complex of buildings?.

[50%]

Perception of thermal comfort depends on 6 factors:

a) Air-temperature
b) Humidity
c) Mean Radiant Temperature
d) Wind Velocity
e) Clothing Level
f) Activity Level

These are measured as follows. Air Temperature and humidity are usually measured together with a whirling hygrometer. The dry bulb gives the air-temperature, while the wet bulb temperature will always be below the dry bulb, but the greater the difference, the lower the humidity. The mean radiant temperature is measured using a globe thermometer which consist of an ordinary thermometer in which the bulb is contained within a black sphere. The latter acts as a black body radiator and gives a measure of the mean temperature of the surrounding surfaces as this can have a significant effect on thermal comfort perception. The globe thermometer must be held at arms length to minimise the effect of the observers body heat on the reading.

Wind velocity is measured using an anemometer, but for most indoor situations, the velocity is so low that it can be approximated to zero. The clothing level is a somewhat imprecise measure and depends on the level of clothing a person is wearing. A typical business suit has a "clo" value of unity. Tables are available to assist people make estimates of the "clo" value. The metabolic rate is an estimate of the activity level, and is very imprecise, but it is a significant effect in determining thermal comfort. For activities such as standing, a reasonable estimate is obtained from tables, but for a seated person, it is highly dependant on the time the person has been seated at that locations. This is because previous activity will have been at a higher rate, and it will be some time before the body adjusts down to the normal seated level of 40 kcal/m^2/hr.

Fanger (1970) completed the most extensive set of results done on thermal comfort, and much of the work derives from his pioneering work. A good answer would demonstrate that student has read parts of Fanger's Book.

Thermal Comfort is an individual matter, and no two people will react the same in the same environment. A scale ranging from –3 (very cold) to +3 (very hot) is used. Using Fanger's Theory it is possible to predict what the predicted mean vote (PMV) will be for any combination of the above physical parameters. This mean vote is the prediction if a large number of people were questioned. Even in the optimum environment there will be people who vote below –2 or above +2, and at the optimum temperature, 2.5% of people will always feel to cold, and 2.5% will always feel too hot. Many people will adjust their clothing level to compensate, but sometimes present day fashions limit what can be done here.

In a good management strategy, individuals in selected representative locations should be asked to vote on the scale +3 to –3, and at the same time, the relevant six physical parameters should be determined. On the basis of such surveys, positions in buildings which are too hot or too cold may be identified and appropriate action taken. If this objective information is not available, then there is a danger that managers will respond to complaints alone, which by definition will tend to be people who are at the extremes of comfort perception. If for instance a person votes –3, and the predicted mean vote is close to zero (i.e. optimum for a large group), then raising the temperature in response to the individual will cause the PMV to deviate from optimum and increase the percentage of people dissatisfied.

A good answer will explore alternative uses to which the data might be put. For instance if there are several locations, then plotting the actual mean vote each building against the mean temperature in that building will allow the optimum temperature in the organisation to be identified (i.e. where the vote is zero). Appropriate action might involve reducing the temperature in those buildings where higher than optimum temperature are found.

4. Describe how a combined cycle gas turbine station differs from a conventional steam turbine.

[20%]

A combined cycle gas turbine station is to be used to supply both electricity and district heating. Data relating to the performance of the different parts of the station are shown in Table 1. Estimate the overall efficiency of the conversion of energy in the station.

Table 2.

Inlet temperature to gas turbine	**1139°C**
Exhaust temperature from gas turbine	**680°C**
Inlet temperature to steam turbine	**547°C**
Condenser temperature	**95.5°C**
Combustion losses	**9.8 %**
Isentropic efficiency of both turbines	**75 %**
Generator efficiencies	**95.5 %**
Station use of electricity	**6 %**
Distribution losses on heating mains	**12.65 %**

[70%]

Summarise the advantages and disadvantages of single shaft as opposed to multiple shaft combined cycle gas turbines.

[10%]

Descriptive part

Energy in the form of electricity or mechanical energy involves a conversion from heat energy in a steam turbine. This process is inefficient and is constrained by the Laws `of Thermodynamics, and in particular the second Law. In a conventional steam generating station, the upper temperature is limited to around 600°C because of the properties of steam. The exhaust temperature to the condenser will be around 30°C in normal generation or around 90°C in the combined heat and power mode. In normal generation the Carnot (theoretical efficiency) will be around 60%, while technical inefficiencies will restrict the actual efficiency to around 45 – 50% (the isentropic efficiency is a measure of the technical inefficiency).

A Gas Turbine by itself has a good high temperature performance with an inlet temperature usually in the range 1100 – 1200 °C, but the outlet temperature is also high (around 600 – 700°C) which means the practical efficiency is limited to around 20 – 25%.

Combining the good high temperature performance of a gas turbine with the good low temperature performance of a steam turbine gives an overall efficiency of around 50%. This is a combined cycle Gas Turbine (CCGT).

Numeric Part

Carnot efficiency of Gas Turbine = ((1139+273) – (680+273))/ (680+273) = 32.5%
*Actual efficiency = 32.5 * isentropic efficiency = 32.5 * 0.75 = 24.38%*

Carnot efficiency of Steam Turbine = ((547+273)-(95.5+273))/(95.5+273) = 55.1%
*Actual efficiency = 55.1*0.75 = 42.30%*

1 unit of fuel in > 1 – 9.8/100 = 0.902 units of energy into gas turbine

*electrical energy out from gas turbine = 0.902 * 0.2438 * 0.955 = 0.210 units electrical*
(0.955 is generator efficiency)

heat out from gas turbine = 0.902 – 0.2199 = 0.6821 units

assuming no heat losses between gas turbine and steam turbine

energy into steam turbine = heat out from GT.
*electrical output from steam turbine = 0.6821 * 0.4230 * 0.955 = 0.269 units electrical*

Total electrical output = 0.210 + 0.269 = 0.479

But 6% of electrical output is used on station itself
*So net electrical output is0.479 * 0.94 = 0.4502. unit electrical*

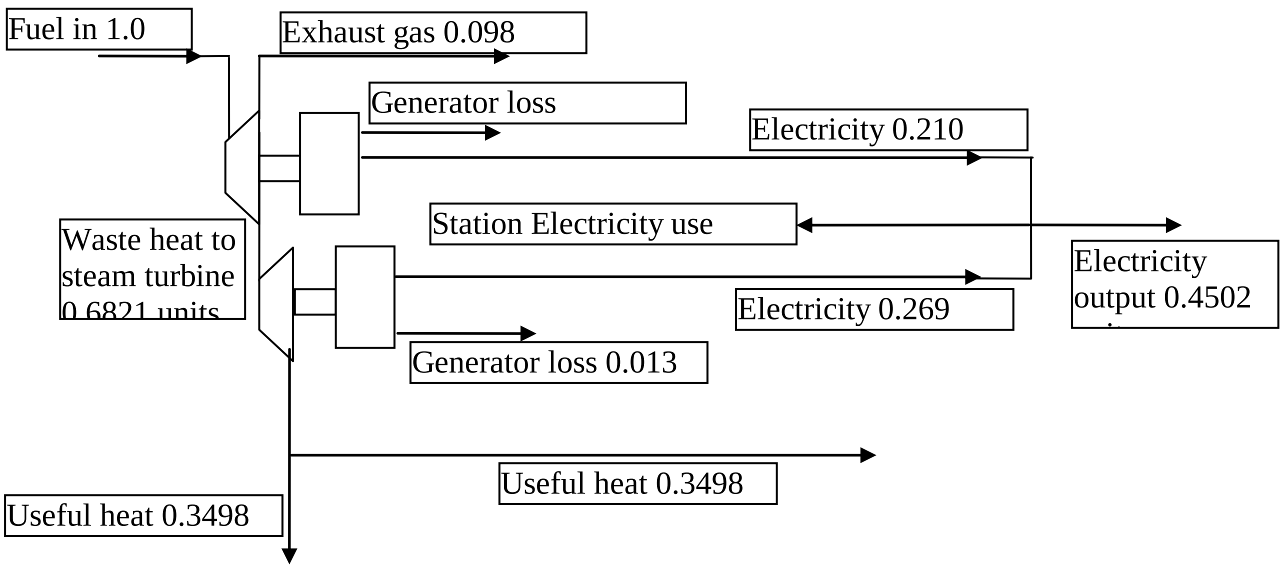
Heat output from steam turbine = 0.6821 – 0.2817 = 0.4004 units thermal
But 12.65% is lost in distribution

*Therefore useful heat out = 0.4004 * (100 – 12.65)/100 =0.3498 units thermal*

Total useful energy out = 0.450 + 0.3498 = 0.80

So overall efficiency is 80%
====

Credit will be given for an answer which shows a flow diagram such as follows.



Early CCGT systems have separate turbine/generator shafts for the gas and steam turbines. Indeed it is not uncommon for two or more gas turbines to feed a single steam turbine. More recent developments have seen the gas turbine integrally coupled to the steam turbine and generator on a common shaft. The main advantage of the common shaft appears to be a slightly increased efficiency as there are less losses between the two turbines. However, a single shaft system has greater flexibility in that the gas turbines can be used alone and as these have a rapid response could be used by themselves to help with peak demand.

6. Explain how you would deconvolute the published energy statistics to determine the trends in energy efficiency of vehicles over the years. How would you use this information to estimate future energy requirements,

[30%]

Table 2 shows a summary of the Transport Statistics from Table X.YY of the ENV Data Book. Estimate the total energy consumption by light vehicles in 2025 if the fuel efficiency of vehicles improves by 25% on the 2002 figure by that time. Clearly state any assumptions you make.

[70%]

Table 2

Year	Number of Vehicles	Energy Consumption (PJ)	Distance Travelled per vehicle (km)
1965	9659000	547.1	13956
1970	12293000	719.9	14260
1975	14751000	812.1	13904
1980	16233000	957.6	14852
1985	18161000	1030.1	15368
1990	21989000	1252.3	17090
1995	22722000	1174.4	17410
2000	25665000	1185.7	16700
2001	26443000	1160.7	16485
2002	27165000	1149.9	16470

Descriptive part

A plot of energy consumption against time as shown in Fig. A1 shows an increase in consumption till the mid 1990's and then a slight fall since that time.

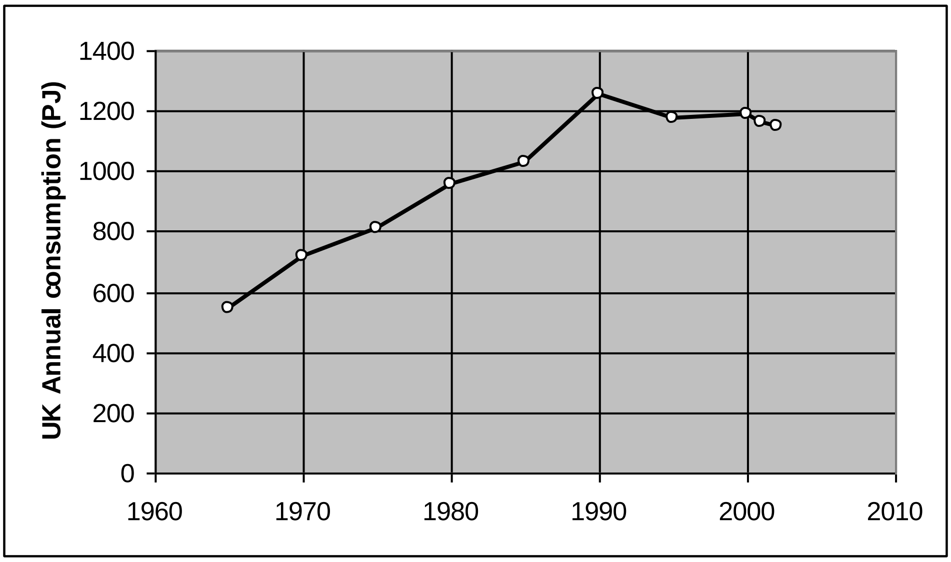


Fig. A1. Energy consumption in Light Vehicles

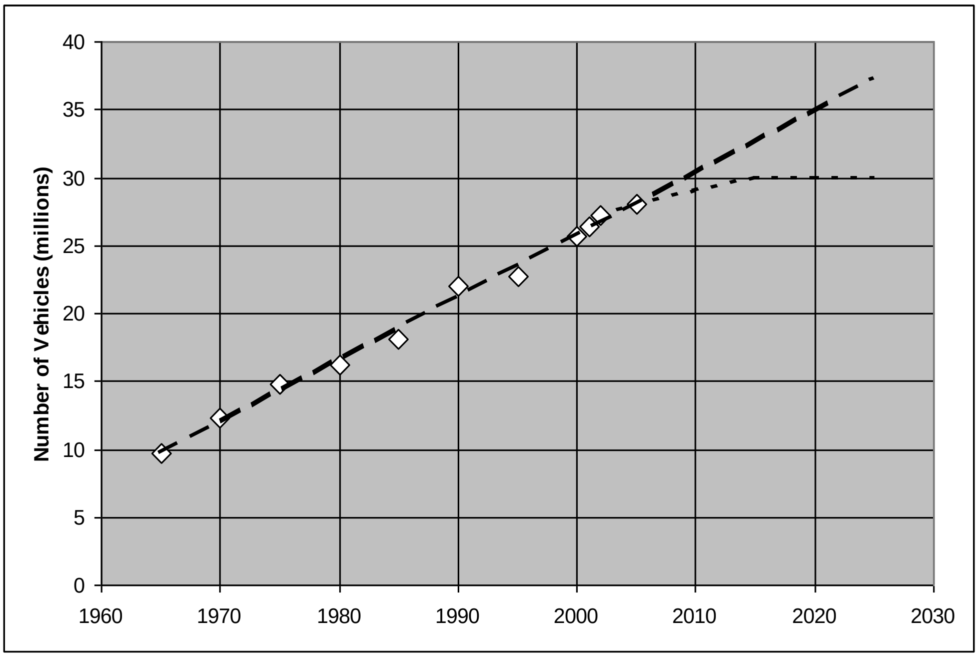
However, this graph cannot be used to predict future trends as three very separate things are happening.

1) *the fuel efficiency is improving*
2) *the vehicle ownership is increasing*
3) *the number of kilometres driven per vehicle is changing over time.*

To predict future trends, it is necessary to separate out the component parts and obtain an actual efficiency of vehicles in terms of energy per kilometer driven, and separately examine the trends in vehicle ownership and distance travelled. The efficiency is obtained by dividing the energy consumption by the number of vehicles and the distance driven.

	UK Annual Consumption (PJ)	Number of Vehicles	Distance travelled (km)	Fuel efficiency (MJ/km)
1965	547.1	9659000	13956	4.06
1970	719.9	12293000	14260	4.11
1975	812.1	14751000	13904	3.96
1980	957.6	16233000	14852	3.97
1985	1030.1	18161000	15368	3.69
1990	1252.3	21989000	17090	3.33
1995	1174.4	22722000	17410	2.97
2000	1185.7	25665000	16700	2.77
2001	1160.7	26443000	16485	2.66
2002	1149.9	27165000	16470	2.57

Note: it is not necessary to evaluate the Fuel Efficiency every year – able students will recognise that only the last year needs to be evaluated.



For vehicle ownership and distance travelled, graphs should be plotted as shown.

Fig. A2. Vehicle Ownership

From 1965 to 2002, there is a strong linear relationship. If this continues until 2025, then there will be 37.268 vehicles. However, there will eventually be a saturation, and evidence from other countries suggests that saturation will occur at around 0.55 vehicles per head With a population of

60 million this suggests a figure of 35 million. On the other hand, proactive transport measure (including road charging, increased fuel etc) could lead to a lower level of say 30 million as shown in the graph..

Distance travelled has declined slightly in recent years and this is attributed to increased occurrence of two car families. It seems reasonable to project a distance travelled at 16 000 km per annum, slightly less than present values.

If the fuel efficiency improves by a further 25%, then the projected energy requirement per km will be

$$2.57 * 0.75 = 1.928 \text{ MJ/km}$$

There are thus three possible scenarios depending on the assumptions on vehicle ownership.

1) business as usual = 1.928 * 16000 * 37.268 / 1000 = 1149.4 PJ or almost exactly the same as present.

2) saturation constraint = 1.928 * 16000 * 35/1000 = 1079.68 PJ (a 7% reduction)

3) conservation constraint = 1.928 * 16000 * 30/1000 = 925.44 (a 20% reduction).

It should be noted that any sensible scenario giving a range between the lower and upper values would be possible, but a clear statement of the assumptions must be made.

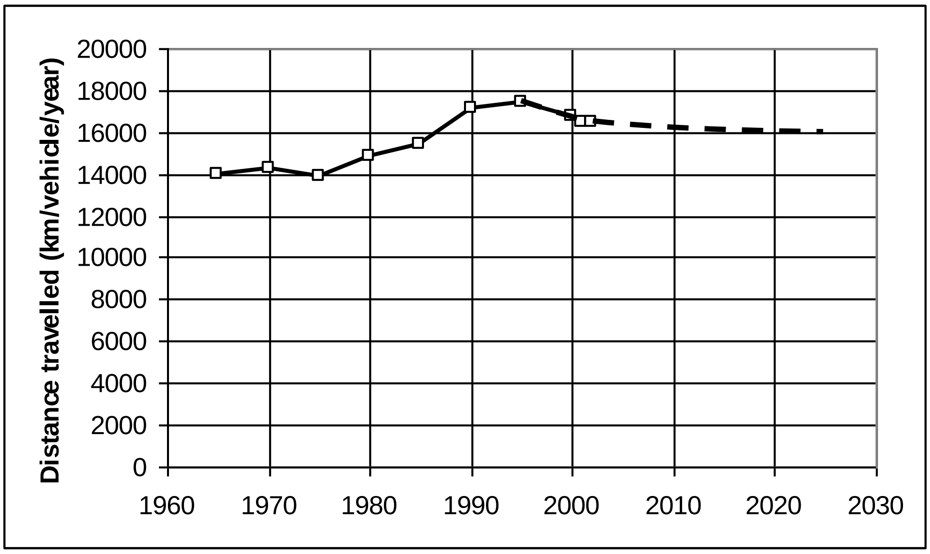


Fig. A3. Distance travelled.

A good answer will consider/discuss (either numerically or descriptively) the issue of different scenarios

6. Critically review the different methods which have been used to demonstrate compliance of Section L of the Building Regulations since 1994. To what extent have these helped or hindered reductions in energy consumption in the Domestic Sector in the UK?

[90%]

What revisions to section L are currently being considered for the next version of the Regulations. Are there any changes you would wish to see ?

[10%]

Approved Document L specifies the requirements for Conservation of Fuel and Power in the Building Regulations. Until the 1994 revision, the Approved Document was a single section, but in 2002 it was divided into two – L1 (dealing with domestic buildings) and L2 (dealing with non- domestic buildings). Generally, the requirements for domestic buildings have been more stringent than for non-domestic buildings.

Historically, there has been always been an improvement in the U-values for the fabric components (roof, floor, windows, walls) from the previous revision, and this was also apparent in the recent revision of 2000 which was implemented on 1st April 2002.

A reduction in U-values for the fabric components will always improve energy efficiency and lead to a lower energy demand. However, there is no requirement to meet a specific ventilation air-exchange rate, and this is a deficiency. There is provision for pressure testing buildings and this will provide an indication of exactly what the ventilation rate is, but there is little or no guidance as to a requirement for meeting a particular standard. A problem is the difficulty in specifying an actual air exchange rate, or what to do with a building which does not actually meet up to the required pressure test specifications.

With ever improving U-values, the contribution from ventilation increases, and in a modern house could amount to 50% or more of the energy requirements (even with draught exclusion), unless heat recovery schemes are in place.

In the 1994, compliance could be achieved by one of three methods

1) *Elemental Method*
2) *Target U-value*
3) *SAP Rating*

In the 2002 regulations, the SAP rating no longer was a procedure for compliance, although such a calculation was still required. However, a new Carbon Index was introduced in those regulations as an alternative method for compliance.

There are thus four separate methods that need to be discussed.

Elemental Method

This method specifies the maximum U-values permitted for an fabric component, and furthermore also specifies the maximum glazed area. Compliance is automatically achieved if the U-values are all below the required levels. Nothing is said about ventilation.

Target U-Value.

The target U-value Method once again looks only at the fabric elements, but aims to provide a degree of flexibility into design. Thus an improvement in wall insulation can be traded off against an inferior roof insulation, or the glazed area may be increased above the Elemental Value, provided that the insulation elsewhere is improved.

Compliance by this method is achieved provided that the aggregate fabric losses i.e. $\boldsymbol{\Sigma}\ \boldsymbol{U_i A_i}$ *is less than the equivalent value had all the components conformed to the elemental method. In the above formula,* U_i *is the U-value of the* i^{th} *fabric component and* A_i *is the corresponding area of that component. In the 2002 regulations, there is a further modification which attempts to factor in whether and efficient heat supply source is being used or not.*

The consequence of the Target U-value method is to give minimum compliance, rather than to promote energy conservation. Good practice in one area can be offset against poor practice elsewhere.

SAP Rating

The SAP rating attempts to take into account not only the relevant U-values, but incorporates estimates of the overall running costs of the building. In this respect it gives indication on how the ventilation is to be incorporated, but gives no requirement for a specific level to be reached. In addition, the calculation incorporates aspects of the control of the heating system, the efficiency of the heating appliance, requirements for hot water, and incidental heat gains.

To this stage it has a worthy aim. However, the monetary costs of the fuels are then required in the final part of the analysis and this can distort figures considerably. [for instance, the standing charge for electricity is omitted, but the standing charge for gas is included]. With the large number of different tariffs, specifically published ones must be used, and since inflation varies there is need for an Energy Cost Factor which is declared and supposed to take account of fuel price inflation.

Compliance was achieved is a SAP Rating between 82 and 84 (depending on size of house) was achieved

The advantage of the SAP Rating method is that it looks at overall running costs, however, there are numerous deficiencies:

1) *This is an extension of the trade-off possible with the Target U-value method. However, in this case, poor insulation standards can be compensated by improved appliance efficiency. The problem here is that the lifetime of the appliance is shorter than that of the house, and there is no guarantee that any replacement would have at least the efficiency of the original appliance. The consequence is that the performance of the house may degrade with time.*
2) *The use of the Energy Cost Factor is an unnecessary and significant complication to the analysis, and can produce the wrong message – for instance switching from gas to inferior oil can improve the SAP rating.*
3) *The SAP Rating (1994) was supposed to go up to 100, but in practice a theoretical maximum of 115 was possible.*
4) *The SAP Rating was abolished as a compliance method from 1st April 2002, but calculation are still required, and the information is used by Estate Agents for selling houses. However, though the methodology is very similar, there are a few important points of difference. The key difference hinges around the Energy Cost Factor which was changed to allow for new prices. The problem with this is that to keep the same SAP rating for older properties built under the 1994 regulations, the scale had to be extended to 120, and the likelihood of values over 100 is increased. This causes confusion particular with SAP ratings in the range 80 – 100 as people tend to think these are good, whereas the scale actually goes up to 120.*

Carbon Index (2002 only)

The Carbon Index method (Building Regulations 2000) was introduced from 1st April 2004 as a means for compliance. The basic idea is to provide a scale of 0 – 10 to relate to carbon dioxide emissions, with 10 being good, and 0 very poor.

The basic compliance methodology follows the SAP rating approach, but excludes the controversial Cost Factor aspects. The calculation ends with a computation of the carbon emissions associated with the building per unit area. This is translated to the 0 –10 index by a highly non-linear scale.

Compliance is achieve if the Carbon Index scores 8 or above. This approach is far preferable to the SAP approach, however, there remains a significant deficiency which is not helping energy conservation,. The non-linear scale is such that anything which scores above 10 is classed as 10. Theoretically for a zero emission house, the index could reach 17.7. This means that a house making compliance is in reality only 8/17.7 or only scoring the equivalent of 4.5 out of 10. In this respect, the Index is giving a false sense of performance with regard to conservation. Further it will cause problems when the Regulations are next updated.

Part (b)

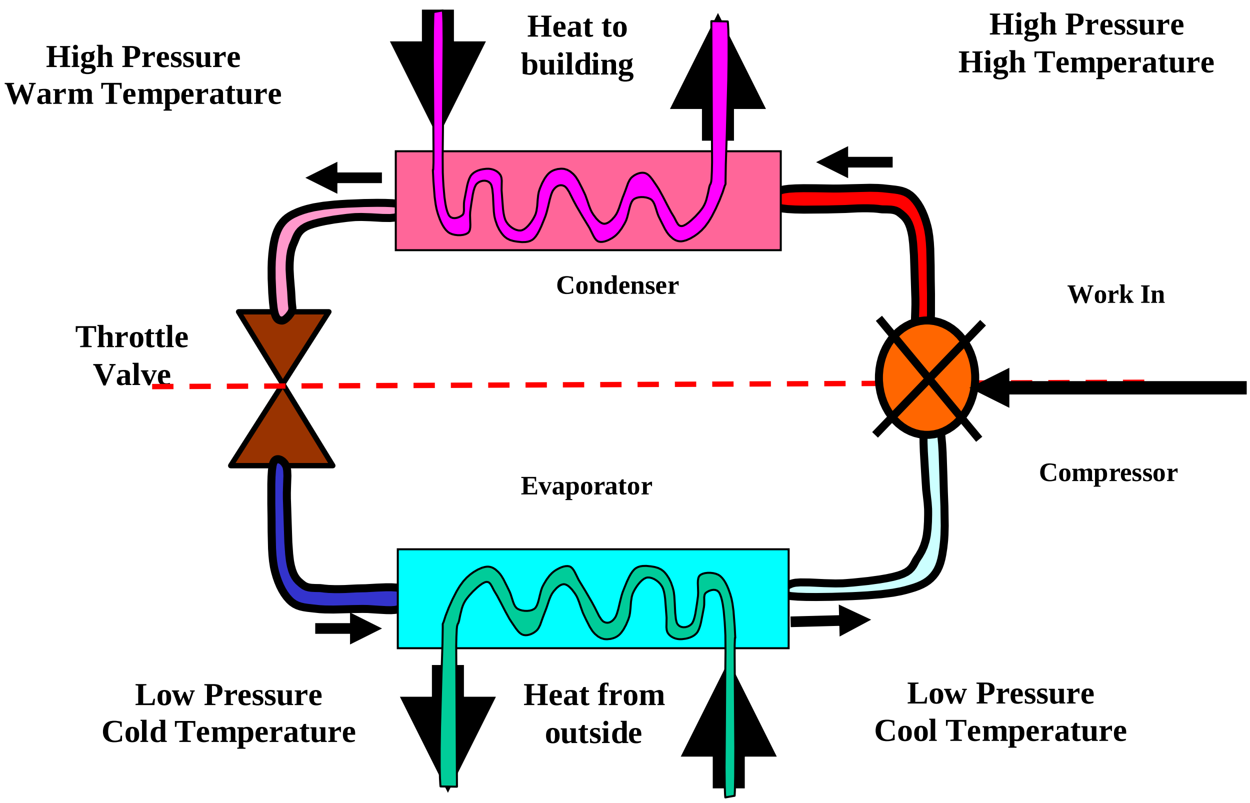
During early 2004, discussions are being held to revise the Regulations for possible implementation in 2005 or 2006. The basic issues here seem a further reduction in U-values, and the possible mandatory incorporation of replacement boilers etc. to a minimum standard. At present, there is no indication of how compliance may be met, and there are also moves to integrate the UK system with the EU system

7. Explain how a heat pump works.

[25%]

Discuss the advantages and disadvantages of the different types of Heat Pump. What factors have limited the exploitation of heat pumps in the UK?

[75%]



A heat pump is a reversed heat engine and allows heat to be "pumped" from a low temperature heat source to a higher temperature heat sink. A refrigerator is the most common example of a heat pump. However, though in common use for refrigeration, only limited use has been made of them for space heating in the UK.

The thermodynamic relationship governing the operation of a heat pump defines a Coefficient of Performance (or COP) which is a measure of the amount of useful heat energy out in terms of energy *put in in the form of work. The COP may be determined from the Carnot relationship for a reversed heat pump:*

$$COP = (T_1) / (T_1 - T_2)$$

Where T_1 is the heat sink and T_2 is the heat source, and both T_1 and T_2 are measured in Kelvin. A typical heat pump operating between $T_1 = 50^oC$ and $T_2 = 0^oC$ yield a COP of 6.46, and even allowing for practical inefficiencies, COPs greater than 3 are readily achievable. In this case 3 times as much heat is delivered to the amount of electrical work expended, the remainder of the heat is extracted from the cold source. Unlike traditional forms of energy conversion in a heat engine, the heat pump effectively works with, rather than against Thermodynamics.

A schematic of a heat pump is shown in Fig. A4

Heat from the cold source is pumped through the evaporator (a contra-flow heat exchanger). He the working fluid – a suitable refrigerant picks up heat and evaporates from a liquid to gas at low pressure (typically 0.5 – 1 bar). The compressor increases the pressure of the fluid to high pressure (typically 5 – 10 bar), before the gas is condensed at high temperature in the condenser where heat is taken up by a fluid which is pumped around the heat sink. The pressure of the working fluid is then reduced via the throttle value to complete the cycle.

The smaller the temperature difference, the higher will be the coefficient of performance.

Part b

Heat pumps may use any suitable low temperature heat source, including the ground (sometimes referred to as geothermal), water (from boreholes, river or lake, or air (directly from outside air or as part of heat recovery). Equally, waste water can be used as a source. Heat sinks may be provided as warm air, hot water, or underfloor heating.

Any combination of heat source and heat sink may be used as shown in table below.

		Heat Source		
		air	**water**	**ground**
Heat Sink	**air**	**air to air**	**water to air**	**Ground to air**
	water	**air to water**	**water to water**	**Ground to water**
	solid	**air to solid**	**water to solid**	**Ground to solid**

Some Examples:-

Air to air:-	Refrigeration vehicles, many simple heat pumps, most air-conditioning plants.
Air to water:-	Proposed UEA scheme in 1981
Water to air	Ditchingham Primary School
Water to water	Norwich Electricity Board Heat Pump during War; Royal Festival Hall. Southampton Geothermal Scheme.
Water to solid	Proposed refurbishment for Norwich Heat Pump
ground to water	ENV demonstration scheme
ground to solid	John Sumner's Bungalow

Heat Sources:- Advantages/Disadvantages

	Advantages	Disadvantages
Air	Readily Available	Noise on external fans
		source temperature low when most heat needed: hence performance inferior at times of greatest need
		source temperature varies greatly:- hence cannot optimise design
Water	source temperature normally higher than air or ground in winter: hence improved COP	not readily available
	source temperature nearly constant: hence design can be optimised	
ground	reasonable availability	capital cost is great if retro-fitted
	moderate source temperature - better than air, worse than water unless coil is in water bearing strata.	
	moderate variation in source temperature: some optimisation possible	

Supplied Heat:- Advantages/Disadvantages

	Advantages	Disadvantages
Air	• relatively low temperature: hence good COP • possibility of heat recovery using mechanical ventilation.	• can only be fitted into hot air systems: • cannot be used with most current Central Heating systems in UK.
Water	• more compact: can be incorporated with existing systems	• higher operating temperature: hence lower COP • Difficult to incorporate heat recovery
solid	• moderate temperature: hence moderate COP	• Cannot be fitted retrospectively: must be installed at time of construction.

8. Describe at least two methods to analyse the consumption of energy required for low temperature heating in a house may be assessed.

[20%]

Explain the differences between the two methods currently used to determine the value of the "Degree-Days" parameter.

[10%]

A house has a heat loss rate of 250 W^{o}C^{-1} and is maintained at a constant temperature of 20^{o}C throughout the year. Table 1. Shows the average maximum and minimum temperatures, while the incidental gains amount to 1125W.

Estimate the number of Degree-days using the two different methods, and estimate the likely error in estimating annual consumption if the more common method is used.

[40%]

The house has 25 m^2 of single glazing with an average U-value of 5.0 W m^{-2o}C^{-1}. The windows are replaced by double glazing units with an average U-value of 2.5 W m^{-2o}C^{-1}

If the incidental gains remain the same, estimate the annual saving in energy following these conservation measures

[30%]

Table 1.

Months	Number of days	Maximum Temperature (^oC)	Minimum Temperature (^oC)
Jan-Feb	59	7.5	0.5
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