Name ....

NBS-M016 Contemporary Issues in Climate Change and Energy

2010

Handout 1

Open Hydro Tidal Stream Device off island of Eday in Orkney Islands. World's first grid connected tidal stream device – commissioned on 19th September 2007.

- **Course Details**
- **Assignment Details**
- **Lecture Notes and related information for first few weeks of course**
- **Some Points for Discussion on 10th February**

Please Note that in previous years the Code for this Module was ENV-M558 and there may be a few residual cross references to that code.

CONTENTS

Introduction

This course is designed to cover a number of the issues relating to the physical aspects of climate change and energy. While Climate Change is important there is also the parallel issue of Energy Security in a world where fossil fuels are being fast depleted. The course will be taught in an interdisciplinary way as some participants in the course will not have the technical background at the start, while for others some of the early content may be very straightforward.

Later in the year in the module on Regulation the topics covered in a more technical way in this course will provide an important introduction to topics such as the Renewables Obligation, Electricity Trading etc. Within this course there will be some related Master Class which will explore some aspects in more depth, at least one as a desk study, while there will be at least one further such class during the autumn.

The initial part of the course will cover basic concepts and principles relating to Energy – a topic which has increasing importance, not only for a social standpoint, but modern society depends heavily on a secure supply of energy. It also is the most significant issue affecting global warming.

Assessment

There will be an item of coursework amounting to 40% of the whole course and an exam (60%). The coursework will have three component parts

- An individual report (70%)
- A verbal Seminar Presentation (10%)
- A joint Group Report (20%).

Details of the Assessment are given later in this document.

Other Resources

You should note that there is a special WEB Page for the Energy Courses, and copies of this Handout and other relevant information for the Course may be accessed from this site.

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

Method of Teaching

This module will run from the first week in February until Easter, and then for two weeks after Easter. In most weeks there will be a lecture Tuesday 09:00 – 10:30 followed after a break either by a second lecture or other activities/discussion time from 10:30-12:00. There will normally be a similar session on the Wednesday mornings. In one week, (beginning 8th March) there will be no session on the Tuesday as NKT will be giving a presentation in Glasgow (this will be rescheduled instead for Monday 15th March). There will be a whole day field trip on Wednesday 10th March. Parts of some of the later sessions will be used for informal group work for working on the assignment.

PLEASE NOTE: This timetable is correct at time of preparation of this handout (20th January 2010). However, circumstances may change and the order and rooms may have to be changed – please consult the Course WEB Site and/or Blackboard for any last minute changes. http://www2.env.uea.ac.uk/gmmc/env/energy.htm

TIMETABLE – correct as of 25th January please see Blackboard/WEB Page for late changes

	Monday	Tuesday		Wednesday			Thursday
	0900 - 1200	0900-1030	1030 - 1200	0900 - 1030	1030 - 1200	to 1700	14:00 – 17:00
Week 1st Feb		Lecture 1: Introduction to Energy	Energy Futures for UK: Start of Coursework	Climate Change: Phil Jones followed by general discussion			
Week 8th Feb		Lecture 2: Units and definitions	Energy Resource Magnitudes 1:	Briefings for topics for Project Work. To be arranged in groups throughout the session. When not in scheduled session – review questions on pages 35-36. Group A 09:00 – 09:45; Group B 09:45 – 10:30; Groups C & D 10:45 – 11:00; Group E 11:00 – 11:20 11:30 – 12:00 review of questions			Master Class: Hard Choices Ahead/ What UEA is doing. Field Visit of UEA Site. Open to SCM and General Students
Week 15th Feb		Energy Resource Magnitudes 2:	Social Issues of Conservation:	Background to Energy Conversion, Conservation Technologies: Elementary Thermodynamics, Heat Pumps, CHP etc.			
Week 22nd Feb		Lecture: Energy Demand/ Balance Tables	Practical Examples of Balance Tables from Different Countries	Nuclear Power - Basics:	Nuclear Power Reactors		
Week 1st Mar		Nuclear Power - Fuel Cycle:	Energy Conservation Buildings – Technical Part 1	Energy Conservation Buildings – Technical Part 2	Energy Management Part 1		
Week 8th Mar		No Session: NKT giving presentation in Glasgow		Full Day Field Trip depart 08:45 return ~ 17:00+. Bring Wet weather clothing			
Week 15th Mar	Coursework Session Seminar Presentations 1 (14 presentation)	Coursework Session Seminar Presentations 2 (4 presentation)	Energy Management Part 2	Electricity Scenarios for the UK	Group Project Work – formulating final scenario		
Week 22nd Mar		Group Project Work – formulating final scenario		Carbon Foot Printing Master Class organised by G. Middleton			Master Class: Resource and Impacts of a selected Renewable Technology:
EASTER BREAK							
Week 12th April		Renewable Energy Technologies 1		Renewable Energy Technologies 2			
Week 19th April		Transport: G Middleton		Transport: G Middleton			

Assignment

AN ENERGY SCENARIO FOR THE UK

1.1 Aim.

The aim of the sessions devoted to the project is to project energy supply and demand in the UK up to the years 2020 and 2030, formulating a coherent energy policy for the UK.

The assignment will involve both individual and group work as indicated below. Each person will be allocated a special task to be come "The Expert" in a particular field and to assess the likely demand or resource potential. The tasks will explore demand and renewable generation. If, as is likely there is a shortfall in supply then this will be covered by continued used of fossil fuels and/or nuclear.

The coursework will be assessed in three separate parts as listed below and constitute 40% of the assessment for the course as a whole with 60% coming from the examination.

There will be three separate parts:-

a) **a seminar presentation (effective percentage of overall project mark - 10%)** **given on Monday/Tuesday 15th /16th March.** This should last no more than **8** minutes and allow up to 2-3 minutes for questions. Presentations must be available for loading onto computer by 17:00 on the previous day.

b) **a report (effective percentage of overall project mark - 70%) submitted on** Wednesday 16th March. This report should be a maximum of 2500 words, although credit will be given for conciseness. The report may cover any aspect of your chosen area – e.g. technical, economic etc, but must include, either in the body or as an appendix a table showing your key projections for the years up to 2030. In the case of demand sectors these should also include a split between different fuel types. You may wish to incorporate questions/queries raised during your verbal presentation.

c) **a group report (effective percentage of overall project mark - 20%) - submitted on** Tuesday 13th April. This should be no more than 2000 words and should be concise with no more than 3 figures as illustration. Any barriers or drivers that need to be addressed to ensure success of your policy should also be addressed. In the unlikely event of disagreement with the group on an overall policy, it is permissible to have a report covering aspects of agreement followed by a majority report then a minority report. In this case the word limit will be judged on the basis of the combined length of the general part of agreement together with the longer of either the majority or minority report. In all cases, the report should be signed by all members of the group. In the case of a report split between majority and minority reports, the agreement mark will still remain the same mark for the whole report.

The marks for (a) will be based on peer assessment moderated by faculty. The marks from (c) will be the same for all members of the project group.

1.2 Organisation

There will be several session available for completing this assignment, some will involve working from the whole group and specific times have been set aside for this informal work

The sessions for which specific times have been allocated will be arranged as follows:-

Session 1 during the second part of the session on Tuesday 2rd February).

There are 18 separate tasks to complete and each member of the group will undertake a different task. It is thus important that the first part of this session is spent in allocating the different tasks and possibly a group leader for this session. On other such sessions you are encourage to have other group leaders.

The aims for this first session are thus

1) to allocate specific tasks to each member
2) to discuss general philosophy of the group – see the questions listed below in section 1.3.
3) to answer (in written form) some key questions which will be needed by some members in the group in their research. These will be posted on the WEB for reference. If as a result of research, one or more people wish to modify the general philosophy, then that is in order, provided you meet informally to discuss the changes.

In addition to this work in the first session, and before the next session, members of the group should attempt to identify the UK and Global resources of the key resources of coal, oil, gas, and uranium.

Session 2 Wednesday 10th February. This will be a briefing session where you can individually ask advice from Dr N.K. Tovey. The briefings will be organised in groups of topics – see Timetable. On the Tuesday session (8th March) NKT will be in Glasgow giving a presentation and you will have the full period available for you to discuss issues as a group and/or to do individual research on the internet or in the Library.

Sessions 3&4 Monday 15Th and Tuesday 16th March will involve individual presentations to other members of the group regarding the projections of your particular area. The seminar presentations should concentrate primarily on projections and assumptions behind them and any drivers or barriers to these – e.g. subsidies etc. The presentations will be limited to 8 minutes each allowing 2 - 3 minutes for comment by other members of the group. Other members may suggest projections are too high or too low for instance. The presentation will constitute 10% of the total marks for the project.

More information about the format of the project presentation is given in section 1.7.

If time permits, agreed projections will be recorded at the ends of each sessions.

Sessions 5 & 6 will be held on 17th and 23rd March and will be timetabled informal sessions so that all members of group can work together finalising assignment. This will begin by the group agreeing on final projections for each subject area before finalising the group report

More information on how to make efficient use of these periods will be given in a supplementary handout.

The individual part of the coursework will involve a report on the specific topic you undertook. In this you are free to slant the report either from a technical stand point, and economic one, a political stand point, or even to go into depth about the methodology of how you developed your projections. Some of the best reports in the past have chosen the last method, but there have also been excellent reports choosing the other approaches. Whichever approach you decide you MUST include tabular or graphical information about your projections.

1.3 The Task

Energy is an important part of every day life, but energy policy decisions have a life span far longer than the time scale of a normal Parliamentary session. Decisions taken now will take at least 10 - 20 years before a significant difference will be seen. It takes 7 years + to build a conventional power station, and each one of these (if replaced say by wind turbines) would typically require 1000 to 2000 such turbines (depending on size of station replaced) and these too will take some time to build. Equally, new measures say for fuel efficiency in vehicles will take 5-10 years to become fully effective because of the life span of the average car.

Each member of the group will tackle a specific part of the project either relating to the demand or the supply side. Each person will be expected to concentrate primarily on his or her allotted topic, but to contribute to group discussions as a whole in the formulation of the energy strategy for the UK.

During the first session, your first objective will be to allocate the various projects among members of the group and to discuss several key points which will affect the development of the project. The separate projects are:-

A) Energy Demand

1) domestic sector requirements
2) industrial sector requirements
3) transport
4) commercial/other sector requirements

B) Renewable Energy Resources

5) solar energy
6) wind energy
7) wave power
8) tidal
9) hydro power
10) Biomass – non transport
11) Biofuels (i.e. biomass transport)
12) energy from waste
13) geothermal (not heat pumps)

C) Energy Conservation

14) CHP/ Heat Pumps

D) Infrastructure

15) HVDC networks in North Sea and Irish Sea

E) Fossil Fuels

16) Gas
17) Oil
18) Coal

If there are 19 people in the group then additional people should investigate fuel cells and the hydrogen economy during the scenario period .which will also have a bearing on the transport sector.

If your group has fewer than 18 people, then you should omit the following topics

Number in Group	Omit Topics
17	**15**
16	**15 & 13**
15	**15, 13, & combine (10 and 11)**
14	**9, 12, 14 & combine (10 and 11)**
13	**13, 15, 16,17, & 18**
12	**13, 15, 16, 17, 18 & combine (10 and 11)**
11	**13, 14, 15, 16, 17, 18 & combine 10&11**
10	**12, 13, 14, 15, 16, 17, 18 & combine 10&11**

Once you have allocated tasks, you may wish to nominate a group co-ordinator.

The following questions should be discussed during the first session, and a short written answer to each (no more than 2/3 sentences) should be handed in at the end of the practical period. These will be distributed to all members the your group so that each of you can refer to the groups general philosophy when doing your own project.

Questions to Consider in the practical Period in Week 1 - WRITTEN ANSWERS TO BE HANDED IN AT END OF PRACTICAL IN WEEK 1.

The final scenario that the group produces should be consistent with the answers you make to the questions. You are free to change your mind, but this must with the agreement of all member, but in that case, there should be an Appendix to the final report indicating the circumstances which led you as a group to change your opinion.

The answers to these questions will be posted on the website.

1) What do you expect the population to be in the target scenario years of 2010, 2015, 2020, 2025 and 2030? Data of population changes and Government Projections are shown in Table 1.1 overleaf.

2) What impact will changing household size have?

3) Will you allow people to freely choose which of the available fuels they use?, and for what purposes? If not what sort of constraints will you impose. Thus if you proposed development of city wide CHP in Denmark, then consumers would be denied the option to switch between fuels?.

4) Will you allow freedom of mobility? If not, can you reconcile the problem that you might be restricting the car ownership to those who have one already. Also what effects would such a decision have on the car industry on future employment levels. Alternatively, would you consider rationing each motorist to say a specific amount of petrol a month. How would you implement such rationing? Investing in Public Transport might be an answer, but not the whole answer, as people have now become used to mobility which has allowed

activities which even if public transport were greatly increased, they would have to curtail unless they continued to use their car. What about air travel?

thousands

Mid Year	Population	Births	deaths	Inward Migration	Outward Migration	Net Migration
1955	50,946.10	789.3	595.9	n/a	n/a	n/a
1965	54,349.50	997.3	627.8	n/a	n/a	n/a
1975	56,225.70	697.4	662.5	n/a	n/a	n/a
1985	56,554.00	750.5	670.7	214	177	37
1995	58,024.80	731.9	645.5	309	235	74
1996	58,164.40	733.2	636	318	249	69
1997	58,314.20	726.6	629.7	307	255	52
1998	58,474.90	716.9	629.2	355	282	74
1999	58,684.40	700.0	632.1	428	273	155
2000	58,886.10	679.0	608.4	461	299	162
2001	59,113.50	669.1	601	487	339	148
2002	59,323.70	668.8	605	514	360	154
2003	59,557.80	707	603	539	353	185
2004	59,846	717	591	601	338	263
2005	60,209	734	575	576	387	189
2006	60,587	758	571	605	406	198
2007	60,975	791	570	561	375	186
2008	61,383					
2011	62800	The data above are the latest available and was published in August 2009. The figures on the left are estimates. Both sets of data were taken from the UK Office of Statistics WEB site. .				
2016	65000					
2021	67200					
2026	69300					
2031	71100					

5) Will you allow domestic consumers freedom of choice to purchase new products as and when they become available, or will you restrict the range of products?

6) What level of growth in the economy do you envisage? How will this be distributed between different industries?

7) Should Britain aim to be self sufficient in energy resources with no net imports even when the oil runs out? - coal conversion techniques could permit oil to be produced from coal, but only from a significant increase in coal demand. Alternatively will you allow coal imports at present, and to what extent. If you allow only a modest import would you be prepared to open up large pits if this becomes necessary to cope with demand after 2000?
If you select the import (i.e. not self sufficient) option, then as this is the easier option, as potentially no internal fuel conversion will be needed.

Whichever option you choose, the group element of the work can be awarded a bonus of up to 5% of the mark awarded if
a) with the self-sufficiency option you demonstrate that this can actually be achieved,
b) with the import option you explore the world wide situation regarding the imported resources together ith the increased competition for other countries. T

8) What is the groups reaction to the use of nuclear power.

possibilities:-

a) stop nuclear power production immediately or within a short time span.
b) run nuclear power plant until end of their life spans see below.
c) phase out nuclear power by a given date.
d) replace existing nuclear plant with more modern ones as they come to end of their lives, but no expansion.
e) a gradual expansion in nuclear power
f) a rapid expansion in nuclear power (similar to that in France in late 70s and 80s).

9) Any other points you consider relevant. - .e.g security of energy supplies

1.4 General Points for All Members of the Group

All projects should make their estimates in **PetaJoules** (i.e. J x 10^{15}) so that you have a common currency to work with during the final deliberations of your group. You should also provide estimates of your projections for each of the following years:- **2010, 2015, 2020, 2025, and 2030. In addition you should also give the figures for the present (i.e. 2007/8).**

1.5 Sources of Information

While you may begin on your topic by general reading, you should aim to get your own data from statistical records, or by consulting the numerous papers in the Energy Paper Series. For example there have been specific papers on each of the renewable energy sources in the Energy Paper Series. Some topics have had several such Papers. Energy Papers 68 gives the government position on these resources. Also, several KEY DOCUMENTS were published by the Government in recent years:

Energy Review - 2002	Energy White Paper 2003	Energy Act 2004
Energy Review - 2006	Energy White Paper 2007	Nuclear White Paper 2008

Relevant documents associated with the Renewables Obligation and the Renewable Transport Fuels Obligation are of relevance. There are also OECD publications on Renewable Energy and also many individual textbooks on most of the renewable energy resources in the main shelves of the library. You should also consult the journal "Review". For the demand sector projects there are key documents in the Energy Efficiency Series. For more general information which might be relevant for your individual written report, do watch for articles in New Scientist and other popular journals, and even the BBC and newspapers. .

Do remember that though Government projections etc. may be given in Energy Papers 62 and more recently 68, and that these may be used as a guide, but you should attempt to derive your own estimates not just rely on what is published. Extra credit will be given in the seminar presentations and your individual reports if you show evidence of this. An example of how you might proceed is shown here for a wind energy example.

You may read from the literature, for instance, that perhaps 20% of UK Electricity could be supplied by wind energy. How many wind turbines would this be? The current thinking is that turbines of about 2 - 3 MW are the most effective, and that the overall load factor is around 27- 30% (currently this is nearer 28.5% averaged over all wind farms). We currently have just over 4000 MW installed. Thus to provide 20% of the current 80GW+ total generating capacity would require 16000 turbines which have ~80+m blade diameters and are 100m high at the hub. Would this number be acceptable? Since they should be spaced at approximately 10 blade diameters - they would cover about 10000 sq km of land?. How many will have to be constructed each year? Do you think this is feasible in the time span? What about the supply chain? These are all things that you should consider and discuss with members of your group.

1.6 More Specific Guidance

a) Energy Conservation Topics (topic 13)

The technologies here are Combined Heat and Power and Heat Pumps. In countries like Denmark, there are city wide CHP schemes. In the UK there are several industrial schemes, and smaller size schemes such as the installation at UEA. Recently, trials for micro CHP have been undertaken to incorporate these into domestic premises. However, in both the UEA scale and domestic size plant, there is a critical issue of disposal of heat in summer, as, by the laws of thermodynamics, heat must always be rejected when electricity is generated.

b) Energy Resource Topics (i.e. topics 5 to 13 above)

Before the seminar, you should aim to examine the relevant potential for your particular resource over the projected period. Note the emphasis on the word relevant. Thus satellite solar stations, OTEC, and direct steam geothermal, for example, are not potential options for the UK..

For all of these resource projects you might begin by assessing the overall potential, but then temper this with conflicting aspects. e.g. conflicts in damage to environment of tidal/hydro schemes. Further the practicality of such schemes should always be an important consideration. Thus, for example, to say that there is 50 GW of wave power is only relevant if the problems of durability in storm force conditions, problems of mismatch of phase from different devices can be overcome.

You may therefore consider that a lower figure is more relevant. Further if, as has been suggested, a major proportion of wave power might come ashore in Scotland then you should consider the implications of additional transmission lines and their environmental impact. The same applies to the argument for wind power - 'If its not blowing on one side of the country then it is likely to be so one the other'. In other words you may consider the problems of additional grid supply may be constraining in exploiting the full potential of the renewable resource. The main point raised in this paragraph is that you must be realistic and be prepared to defend any claims you make to other members of your group or outsiders.

You should be realistic. For instance, the last Conservative Government made a commitment to have 1500 MW of New Renewable Generation (of all types) by 2000. By the beginning of 2002, only 950 had in fact been installed. Then under the Renewables Obligation we are currently falling well behind the target growth of such renewable with only around 5% generation in 2007. Equally, what exactly does the Renewable Obligation commitment for 10% generation by 2010 actually mean? 10% in 2010 will mean that we shall still have to have exactly the same amount of non-renewable component (even on an optimistic scenario), as until the recession started, just the increase in demand is currently outstripping the implementation of renewable projects.

For all those doing Resource Topics, you may well initially develop your projections based on installed capacity. However, ultimately you must convert this into a quantity of energy in PetaJoules. For this you will need to use a relevant Load factor. i.e. the amount generated in a year will be:-

Capacity * load factor * no of hours in a year.

This will give a value in MWh (if capacity was in MW).

Actual Load Factors for renewable currently in use are shown in the following table.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Load factors (per cent)											
Onshore wind	30.7	28.2	28.2	26.4	29.9	24.1	26.6	26.4	27.2	27.5	27.0
Offshore wind (from 2004 only)	..	..	..	..	..	..	24.2	27.2	28.7	25.6	30.4
Photovoltaic		6.8	7.5	7.6	7.4	5.6	5.6	8.6	8.6	8.8	8.6
Hydro	36.8	38.4	36.4	28.7	34.0	23.3	37.1	37.5	34.8r	38.2	37.4
Biofuels and wastes (excluding co-firing)	65.7	64.1	58.6	61.1	61.2	62.5	62.0r	58.5r	56.2r	56.7r	56.3

You must also consider problems of implementation. By all means consider an optimistic scenario, but also consider a scenario based on central assumptions, and one on pessimistic assumptions. With regard to time scale of development. Thus for **Wind Energy,** do not merely assume, for example, that 10000 MW of wind power might be available by 2012 if your source of reference which suggested that it might was written in 2000. Clearly you must add 10 years to the time scale as we are now 10 years further on. We currently have about 4000+ MW of wind energy, but many recent planning applications for wind turbines have been turned down.

The British Wind Energy WEB Site is a good source for indentifying current and planned projects.

For other energy sources, you should consider whether non-energy matters might have a bearing on their deployment. Solar panels, for example, require significant quantities of additional glass etc., and an adequate time scale to design and build the extra capacity must be considered in your assessment of the rate of exploitation (not to mention the energy required for construction). Further do not forget that solar panels are unlikely to have a life of more than 25 years, so the rate of renewal might become important.

For those doing **solar energy**, you can get an estimate of the potential of active solar energy from solar hot water as follows:-

- On average each household uses 120 litres of hot water at 55^{o}C a day (inlet temperature to house = 10^{o}C).
- there are about 22 000 000 households not all of which are suitable for installing solar panels.
- solar collectors have an efficiency of around 35%.

You can then estimate the maximum potential resource available, but making assumptions as to how many houses could actually have solar panels. Many flats would not, and many other existing houses are shaded in the key directions by other buildings.

Photovoltaic cells are claimed to produce up to 100 kWh per sq m for mono-crystalline cells, around 80 kWh per sq m for poly crystalline and around 60 kWh per sq m for amorphous. More recently grants have become available, but these would require subsidies of 75-80% to be cost effective at present time, way beyond the level presently available.

For those doing **Energy from waste**, then some of the following considerations may be relevant. Burning waste will reduce demand for landfill, but there may be conflicts here if we push for more recycling of paper and plastic as the calorific value of waste will then be reduced. There may also be environmental objections for such plants. Very limited amounts of energy can be produced from sewage, but energy crops can be grown, but it is now believed that many of these are not net energy producers. There are some power stations in East Anglia running off waste agriculture – e.g. Eye, Suffolk (Chicken Litter), Thetford, Norfolk (Chicken Litter), and Ely, Cambridgeshire.

There are numerous possibilities with waste and biomass, but many would only give small amounts of energy overall. However, **BIOETHANOL** and **BIODIESEL** are worth mentioning as these would provide an alternative for transport.

- **Bioethanol** could be blended at up to 10 – 15% with petrol without modification to car engines at present. Flexi fuel vehicles like one version of the Ford Focus can use E85 – i.e. 85% ethanol and 15% petrol., but there are very few vehicles in the UK which can run on E85. The easiest crop is sugar beet, but other woody crops may be digested in second generation reactors.
- **Biodiesel** can be used directly in place of normal diesel, but CANNOT be swapped directly, as particulates flush out from engines which have run on fossil diesel and can block filters etc. A gradual change over is needed. Biodiesel can be obtained from oil seed rape, or vegetable oil.

To assess the potential you should make an estimate of the Land Area required. For instance crops can be grown at a rate of 10 – 20 tonnes per hectare per year, and the calorific value is around 10 GJ per tonne. Biomass for transport would require conversion at an efficiency of around 35%, while the efficiency for electricity generation is around 30%.

Some renewable resources are still technology limited – e.g. tidal current tidal devices and wave power. Although some schemes are planned in next year or so these are still demonstration projects, and it will take at least 10 years to build up even small industries in these areas.

For many of the energy resource schemes, storage may be an important factor. You should in your projections think about the requirements for storage.

For all of you doing resource projections, credit will be given for your own projections rather than merely relying on what has been written elsewhere. Such figures are often notoriously unreliable and we shall expect you to critically review any such projections you use (e.g. in the way outlined for Wind at the end of section 1.5).

b) Energy Demand Topics (topics 1 - 4)

PLEASE NOTE IN THESE TOPICS YOU ARE ONLY EXPECTED TO ASSESS DEMAND – NOT HOW IT IS TO BE SUPPLIED. THUS IN THE DOMESTIC SECTOR – THE QUESTION IS: HOW MUCH WILL THE DEMAND FOR HEAT, HOT WATER, COOKING, APPLIANCES BE IN THE TARGET YEAR. YOU SHOULD NOT CONCERN YOURSELVES WITH HOW MUCH MIGHT BE

OFFSET BY SOLAR (for example|) – that is the remit of the person doing that topic. Equally how much that could be supplied by Heat Pumps/CHP is not in your remit, but what changes in demand there may be by changing the insulation levels/replacement boilers would be.

The key documents to consult here are:-

The first of these are now somewhat dated, but importantly they do give a good indication of the methodology that should be employed.

- Energy use and Energy Efficiency in the UK Transport Sector up to the year 2010. Energy Efficiency Office (HJ 7510.MAR oversize
- Energy use and Energy Efficiency in the UK Domestic Sector up to the year 2000. Energy Efficiency Office (TJ 163.4.ENE oversize
- Energy use and Energy Efficiency in the UK Industrial Sector up to the year 2000 (2 vols). Energy Efficiency Office (TJ 163.4ENE oversize
- Energy use and Energy Efficiency in the UK Commercial and Public Administration Sectors up to the year 2000. Energy Efficiency Office (TJ 163.4ENE oversize

Key Statistics accessible from the WEB Page

- Digest of UK Energy Statistics
- UK Sector Indicators
- UK Energy Consumption
- Energy Trends
- Energy Reports 1994 - 2002 (in Official Publications and on WEB)
- Energy Paper 62, particularl Energy Paper 68 and Updated Energy Paper 68 (available on WEB).

You may also wish to consult the following documents in the Official Publications Room in the Library:-

- Census of Production Statistics
- General Household Survey 1992 and subsequent years
- English House Condition Survey 1991+
- Monthly Digest of Statistics
- Annual Abstract of Statistics
- Electricity Supply Industry Handbook 1989 (it was discontinued after privatisation) gives details of electrical energy use in different appliances in the home.

In the practical in week, 1 we saw a crude method whereby projections could be made for the future. As a starting point, you could get the equivalent historical data for your particular sector, plot this up and then make a projection. Do note that the method of reporting data does sometimes change from year to year so if necessary you may have to use a conversion factor to bring all to a common base. Data in the statistical publications are reported in a variety of units so make sure you convert all consumptions to PetaJoules.

Besides the total amount of energy required and projected for the future, you should also consider how the distribution between coal, oil, gas, and electricity is going to change. This information will be relevant for the final group scenario.

In all sectors you should disaggregate the data into separate sections, so that you can identify increases say in light industry which are likely to lead to INCREASED consumption in the future, and also those sections e.g. iron and steel which are on the decline. Without this disaggregation the true trends may not be seen. For each sector you should estimate the demand into the future (in five year steps from 2010 to 2030). You may wish to impose different growth/decline rates on the different subsections, but whatever you do you should apply a sensitivity analysis by choosing a range of growth rates on either side of your central assumption.

Make sure that you are clear about any growth rates in the individual sub-sections. i.e. will you allow continued growth in personal mobility – continued decrease in household size?

1) For those dealing with the **Industrial sector**, you may consider that an Index of industrial output from other sources of statistics may be helpful in your predictions. Thus you could investigate how energy efficiency in different sectors has been changing in recent years. Also bear in mind any constraints or stimulants (e.g. subsidies) that your group as a whole imposed on the industrial sector. One or two of the earlier Energy Papers do give information on the Energy Requirements for particular industries or products. Otherwise, you may have to lump your groups into Iron/Steel, Chemical, Electrical etc.

2) For those dealing with the **Transport Sector**, you should examine the growth in fuel consumption and also the number of miles driven per vehicle, as well as the growth in the number of vehicles on the roads. At present there appears to be no reduction in the rate of growth of miles driven per vehicle, and this is far outstripping technical improvements in efficiency etc. Unless your group as a whole has decided that there will be restrictions on the use of vehicles, you must assume that given freedom of choice, and improvements to the road network that this increase will continue at least until 2005. You might consider legislation for improved fuel efficiency, but that would take up to two years to get through Parliament, and a further two years before industry could technically copy with such a change - ordering and installing new equipment etc. Further, only new cars would be effected, and with an average life span of ten years it would take that time to become fully effective, and even then there will be > 20% of cars older than 10 years. It is estimated that given the impetus now, it MIGHT be possible to have cars consuming 25% less petrol by say 2006 or so, and 40% less by 2015. However, if you or your group insist on pollution controls, then the improvements will be reduced to about 15%, and 25% (i.e. 21 and 30% improvement) to respectively.

3) For those dealing with the **domestic sector** some of the disaggregated data will have been provided for you in lectures, and you will have noticed the significant growths in both refrigeration and the use of appliances. However, you should in addition consider the effects of conservation. To do this you will need to assess the extent of factors such as how many houses have cavities which can be filled, and how many are filled at present. Similarly, the current extent of loft insulation should be assessed. However, only a proportion of the theoretical savings will actually be made as many people will see the effects as improving comfort standards, a point which is particularly relevant for the poorly heated homes at present. Further do not forget that in the 1950s average internal temperatures of $17^{o}C$ or less were considered adequate. Now the typical temperature is $20^{o}C$ (some sources suggest 21^{o}), and if the American experience is

anything to go by, this may rise further, particularly if the Fashion World continues to produce clothing with less and less insulation value.

In 1991 81% of homes had central heating, and those that do not on average use 50% less energy than those that do (because of lower overall internal temperatures). If steps are taken to eliminate problems such as hypothermia, there will be a consequential rise in energy demand for space heating even if the houses are insulated at the same time. Equally, the trend to smaller and smaller households will mean an increase in demand for the same population (the number of households has a more significant link with energy than population). On the other hand, energy conservation strategies would reduce demand in each household. These conflicting trends might result in a static demand over the scenario period, but that will depend on how things are modelled.

You should aim to set a saturation level of comfort in all houses which might be reached by 2010 - 2015. Do remember that additional energy will be required if EXTRA houses are built to cope with the current problem of homelessness. However, you might consider that new legislation be introduced to produce low energy houses which might use 30 - 50% of the energy requirement under the current standard. Note the new 2002 Building Regulations (see WEB Page for details) made noticeable improvements to conservation standards, but there is still scope for further improvement. . A further point you must not overlook is the replacement rate. Currently about 150 000 – 200 000 houses are built annually, of which 50,000 to 100,000 are additions to the housing stock, while the remainder are replacing older housing (you can get accurate statistics from the relevant publications in Official Publications).. So with a modest increase in housing, and the replacement rate significantly below 1%, low energy housing will not have a significant effect on energy consumption until well beyond 2010+.

You may wish to consider the cost of the insulation measures you propose for existing houses.

4) For those doing the **Commercial and Other Sectors,** the approach you take should be similar to that adopted for the domestic sector, although the data is rather more scanty here. The sectors include, the commercial and retail sectors, public administration, education, and agriculture. You might begin with separating the energy consumption for each of these sector, and then projecting changes in each separately.

C) Energy Conservation Technology Topic (14)

CHP and Heat Pumps could provide a significant part of the demand for space heating both in domestic and commercial buildings, and indeed in industrial processes. You should aim to explore not only the potential, but also the barrier – e.g. what happens in the summer when the demand for heat is low what would happen to electricity generation from CHP etc..

Key sources of information for these topics would be the Energy White Papers, the CHP Association, the Carbon Trust, Energy Saving Trust etc.

D) Infrastructure Topic (15)

This aspect of the project will look at major infra structure issues for the UK energy supply which will include HVDC networks in North Sea and Irish Sea and enhancements to gas supply in UK – e.g. more interconnectors/ Liquid Gas Terminals/Storage.

Already there are constraints on north south electricity supply, although this will hopefully be partly resolved with the eventual approval after 5 years of Planning Enquiry of the Beauly – Denny Line. Nevertheless the will be significant restrictions on what renewable can be deployed if they are at the extremities of UK.

The person doing this project should liaise with those doing renewable energy projects to identify where the best deployment of such renewables is likely to be and what is needed to overcome any constraints. In a similar way infrastructure related to gas use will necessarily interact with the project exploring gas demand.

E) Fossil Fuel Supply Topics (16 – 18)

The aim of these topics is to explore the resources of the fossil fuels (coal, oil and gas) in the UK context. The key questions to investigate are:

1) What is present UK production and how has it changed over the years?
2) What has been the imports/exports of the fuel over the last 20 years or so?
3) What has been the demand for the fuel?
4) What level of self sufficiency has the UK enjoyed and to what extent has this been dictated by economic/environmental matters? – e.g. UK deep mined coal is often more expensive than overseas open cast coal.
5) What is the supply of fuel likely to be in the future and from where is it likely to be obtained?

1.7 The Seminar Presentations

A full informal session is devoted to preparation for your reports on Tuesday 8th march. There will be no formal class, but it is timetabled so all of you can meet together to discuss issues which might affect more than one of you.

The seminar presentations will take place on March 15th/16th. The seminar will be assessed not only for your presentation, but any contribution you may give to the general discussion. Assuming you are using a PowerPoint for presentation, these should be forwarded to NK Tovey by 17:00 on the preceeding day.

Assessment will be in two parts. 50% will come from the faculty and 50% will come from Peer Assessment of the Group. Guidance on this will be given nearer the time.

The order of the presentations will be as indicated in the list in section 1.3. Each person will be given 8 minutes in which to present his or her projections after which there will be an opportunity for other members of the group to challenge assumptions are make comments about the figures given for a maximum of 2 - 3 minutes. In some cases, the presenter may give a range of options and throw it open to the remainder of the group to make a collective decision.

In your presentation you should aim to be concise. Perhaps spend the first two or three minutes setting the scene and indicating any technical or other limitations which will affect your resource or demand (e.g. rate of building wind turbines, or rate of replacing houses with low energy stock etc.). Then clearly state your assumptions before you give your figures. It is often helpful to show graphs or simple tables of figures, but do not try to make a table too complicated by putting in to many figures. Thus in your actual presentation it might make sense to show only current figures and the figures for 2020 and 2030 and have the other figures written down for circulation among members of the group.

If possible, you should enter the agreed figures for each of the 13 projects in the booking sheet on the next page. However, in any case, all group members will be required to hand a written copy of their projections to NKT during the seminar, so these may be collated.

1.8 Preparation of the Group Scenario – first two weeks of April.

The preparation of the group scenarios will take place in two sessions, the first of which is scheduled for 17th March, and the second for 23rd March. During these sessions you must aggregate the data from the presentations and reconcile and discrepancy between supply and demand which will then have to be filled with fossil fuels and/or nuclear. A separate handout will give guidance on this aspect.

TABLE A1.1 AGREED INDIVIDUAL PROJECTIONS - for use during seminar presentations ALL FIGURES IN PETAJOULES

Project	Fuel Type	2000	2010	2015	2020	2025	2030
Domestic Sector	coal						
	oil						
	gas						
	electricity						
Industrial Sector	coal						
	oil						
	gas						
	electricity						
Transport	coal						
	oil						
	gas						
	electricity						
Commercial	coal						
	oil						
	gas						
	electricity						
Solar	thermal						
	electricity						
Wind	electricity						
Wave	electricity						
tidal	electricity						
hydro	electricity						
biomass	heating						
	transport						
	electricity						
waste	heating						
	electricity						
geothermal	heating						
Heat Pumps/CHP	Electricity used						
	Heat Supplied						
CHP	Electricity Generated						
	Heat Supplied						

SUMMARY LECTURE NOTES

1.1 Introduction

Energy is essential for all walks of modern day society and the developed world is typically consuming 5 kW per person. Carbon dioxide levels are rising, and this has caused a noticeable increase in global temperatures (Fig. 1.2) which, if unchecked may cause significant changes to society. Some of the likely effects are:

- Increased flooding in some parts
- Increased incidence of droughts
- Increased global temperatures
- General increase in crop failure, although some regions may benefit in short term
- Catastrophic climate change leading to next Ice Age.

Energy must also be studied from a multi-disciplinary standpoint (Fig. 1.1).

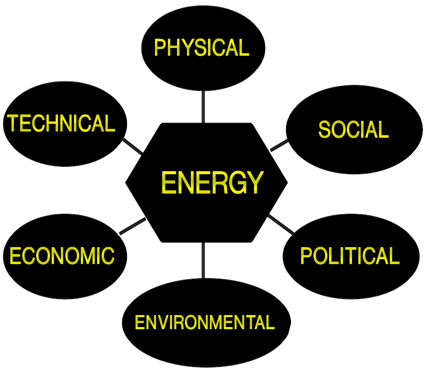

Fig. 1.1 Factors to be considered when studying Energy Issues

1.2 THE ENERGY CRISIS - The Non-Existent Crisis

There is no shortage of energy on this planet, nor has there ever been, nor will there ever be.

There is a potential shortage of energy in the form to which we have become accustomed.

We should more correctly talk of a **FUEL CRISIS.**

1.3 HISTORICAL USE OF ENERGY up to 1800

Man consumes about 15% of energy derived from food in collecting more food to sustain life. To this must be added energy expended in providing/making clothing and shelter.

Two early forms of non-human power harnessed were:-

1) fire
2) animal power

OTHER ENERGY FORMS HARNESSED

1) Turnstile type windmills of Persians
2) Various water wheels (7000+ in UK by 1085)
3) Steam engines (?? 2nd century AD by Hero)
4) Tidal Mills (e.g. Woodbridge, Suffolk 12th Century)

1.4 The First Fuel Crisis

LONDON - late 13th /early 14th Century

- Shortage of timber for fires in London Area
- Import of coal from Newcastle by sea for poor
- Major environmental problems for high sulphur content of coal

Pressure on fuel resources reduced following a halving of population as a result of **The Black Death.**

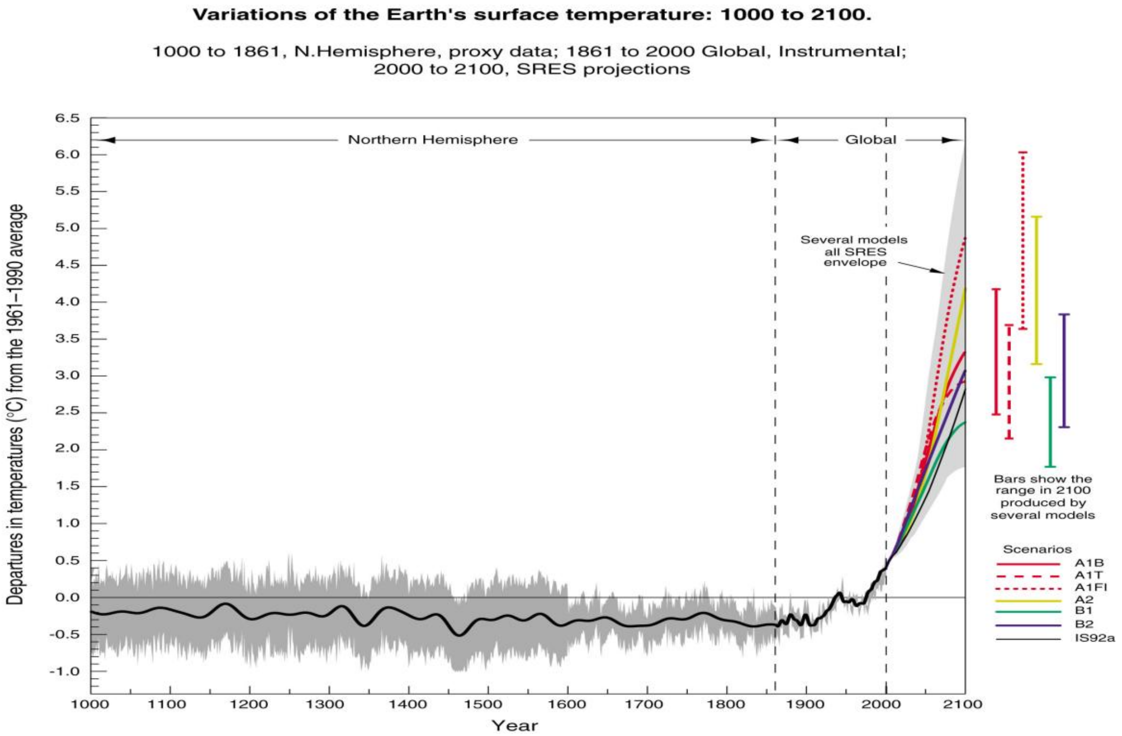

Fig. 1.2 Variation of Global Temperatures over last millenium

1.5 The Second Fuel Crisis:-

UK - Late 15th/early 16th century

- Shortage of timber - prior claim for use in ship-building
- Use of coal became widespread -even eventually for rich
- Chimneys appear to combat problems of smoke
- Environmental lobbies against use
- Interruption of supplies - miner's strike
- Major problems in metal industries led to many patents to produce coke from coal (9 in 1633 alone)

1.6 Problems in Draining Coal Mines and Transport of coal threatened a third Fuel Crisis in Middle/late 18th Century

Overcome by Technology and the invention of the steam engine by Newcommen.

- a means of providing substantial quantities of mechanical power which was not site specific (as was water power etc.).

NEWCOMMEN's Pumping Engine was only 0.25% efficient (see Fig. 1.3)

WATT improved the efficiency to 1.0% (Fig. 1.4)

Current **STEAM** turbines achieve 40% efficiency**, but further improvements are LIMITED PRIMARILY BY PHYSICAL LAWS AND NOT BY OUR TECHNICAL INABILITY TO DESIGN AND BUILD THE PERFECT MACHINE.**

Coal fired power station will never be more efficient than about 45% (even with the most advanced developments in technology). This figure assumed IGCC technology - Integrated Gasification Combined Cycle Stations.

Gas fired CCGT (Combined Cycle Gas Turbine) Stations (of DASH FOR GAS notoriety) are currently 47-51% efficient, and there are prospects that these could improve ultimately to 55% or a little higher.

1.7 Energy Capabilities of Man

Explosive sports - e.g. weight lifting
500 W for fraction of second
Sustained output of fit athlete --> 100 - 200 W
Normal mechanical energy output << 50 W

Heat is generated by body to sustain body at pre-determined temperature:-

approx.: 50 W per sq. metre of body area when seated
80 W per sq. metre of body area when standing.

1.8 Forms of Energy

- **NUCLEAR**
- **CHEMICAL** - fuels:- gas, coal, oil etc.
- **MECHANICAL** - potential and kinetic
- **ELECTRICAL**
- HEAT - high temperature for processes
  - low temperature for space heating

All forms of Energy may be measured in terms of Joules (J), BUT SOME FORMS OF ENERGY ARE MORE EQUAL THAN OTHERS

1.9 ENERGY CONVERSION

Energy does not usually come in the form we what it in and we must therefore convert it into a more useful form.

All conversion of energy involve some inefficiency:-

- Physical Constraints (Laws of Thermodynamics) can be very restrictive leading to MASSIVE ENERGY WASTE.

This is nothing to do with our technical incompetence. The losses here are frequently in excess of 35-40%

- Technical Limitations (e.g. friction, aero-dynamic drag in turbines etc.) are things which can be improved. Losses here are usually less than 30%, and in many cases around 5%.

Some forms of energy have low physical constraints and may be converted into another form with high efficiency (>90%).

e.g. mechanical <--------> electrical
mechanical/electrical/chemical -----------> heat

Other forms can only be converted at low efficiency

e.g. heat ------------> mechanical power - the car!
or in a power station

USE APPROPRIATE FORMS OF ENERGY FOR NEED IN HAND. e.g. AVOID using ELECTRICITY for LOW TEMPERATURE heating

1.10 WHAT DO WE NEED ENERGY FOR?

- **HEATING** - space and hot water demand
  80%+ of domestic use excluding transport)
- **LIGHTING**
- **COOKING**
- **ENTERTAINMENT**
- **REFRIGERATION**
- **TRANSPORT**
- **INDUSTRY** - process heating/ drying/ mechanical power

IT IS INAPPROPRIATE TO USE ELECTRICITY FOR SPACE HEATING

2.11 GRADES OF ENERGY

- **HIGH GRADE:** - Chemical, Electrical, Mechanical
- **MEDIUM GRADE: -** High Temperature Heat
- **LOW GRADE:** - Low Temperature Heat

All forms of Energy will eventually degenerate to Low Grade Heat, and may thus be physically (and technically) of little practical use - i.e. we cannot REUSE energy which has been degraded.

1.12 ENERGY CONSERVATION

- Energy Conservation is primarily concerned with MINIMISING the degradation of the GRADE of ENERGY (i.e. use HIGH GRADE forms wisely - not for low temperature heating!!).

- To a limited extent LOW GRADE THERMAL ENERGY may be increased moderately in GRADE to Higher Temperature Heat using a HEAT PUMP.
- However, unlike the recycling of resources like glass, metals etc., where, in theory, no new resource is needed, we must expend some extra energy to enhance the GRADE of ENERGY.

2. UNITS

The study of **ENERGY** is complicated by the presence of numerous sets of ***UNITS OF MEASURE*** which frequently confuse the issue.

*It is **IMPORTANT** to recognise the DIFFERENCE between the **TWO BASIC UNITS:-***

a) the JOULE (a measure of quantity)
b) the WATT (a *RATE* of acquiring/ converting/ or using ENERGY).

2.1. QUANTITY OF ENERGY

The basic unit of Energy is the **JOULE**.

It is defined as the *WORK DONE* when a force moves through a distance of 1 metre *in the direction of the force.* The SI unit is the JOULE, and all forms of Energy should be measured in terms of the JOULE.

FORCE is measured in **Newtons (N)**
DISTANCE is measured in **metres (m)**

Thus WORK DONE = Newtons x metres = Joules.

A 1 kg lump of coal, or a litre of oil will have an equivalent Energy Content measured in Joules (J).

Thus 1 kg of UK coal is equivalent to 24 x 10^6 J.
or 1 litre of oil is equivalent to 42 x 10^6 J.

The UNITS of (QUANTITY of) ENERGY in use are shown in the Table 3.1:-

In earlier literature, the situation is confused further by the fact that both the US (short) ton and Imperial (long) ton are used in place of the metric tonne.
Finally, the situation is further confused in that European Coal has an Energy content 20% than the equivalent weight of UK coal.

Factors to convert one quantity of Energy into another are given in the Data Book. Always use the SI unit (JOULE) in all essays etc. If necessary cross refer to the original source unit in brackets.

CONSIDERABLE CONFUSION SURROUNDS THE USE OF THE KILOWATT-HOUR -- DO NOT USE IT!!!!

• JOULE (J). • calorie (cal) • erg • Kalorie (or kilogram calorie Kcal or Kal) • British Thermal Unit (BTU) • Therm • kilowatt-hour (kWh)	• million tonnes of coal equivalent (mtce)million tonnes of oil equivalent (mtoe) - (often also seen as - mtep - in International Literature). • litres of oil • gallons (both Imperial and US) of oil • barrels of oil • million tonnes of peat equivalent

Table 2.1 Energy units in common use.

2.2. RATE OF USING ENERGY

The RATE of doing WORK, using ENERGY is measured in WATTS.

i.e. 1 Watt = 1 Joule per second
1 W = 1 J s^{-1}

Thus if we burn a kilogram of coal (Energy Content 24 x 10^6 J) in 1 hour (3600 seconds) we would be using Energy at the rate of:-

$$\frac{24 \times 10^6}{3600} = 6666.7 \text{ W}$$

Equally, a Solar Panel receiving 115 W m^{-2} (the mean value for the UK), the total energy received in the year will be:-

115 x 24 x 60 x 60 x 365 = 3.62 x 10^9 J.

NOTE: THE UNITS:-

KILOWATTS per HOUR
KILOWATTS per YEAR
KILOWATTS per SECOND

are MEANINGLESS (except in very special circumstances).

WARNING: DO NOT SHOW YOUR IGNORANCE IN EXAM QUESTIONS BY USING SUCH UNITS

2.3. SI PREFIXES

milli	**-**	**m**	**x 10^{-3}**
kilo	**-**	**k**	**x 10^3**
Mega	**-**	**M**	**x 10^6**
Giga	**-**	**G**	**x 10^9**
Tera	**-**	**T**	**x 10^{12}**
Peta	**-**	**P**	**x 10^{15}**
Exa	**-**	**E**	**x 10^{18}**

NOTE:-

1) The prefix for kilo is k *NOT* K
2) There are no agreed prefixes for 10^{21} or 10^{24}
3) Avoid mixing prefixes and powers of 10 wherever possible.

i.e. 280 GJ is permissible but not 28000 GJ or 2.8 x 10^4 GJ.

3. ENERGY - DEFINITIONS

3.1 Definition of Efficiency

All uses of energy involve the conversion of one form of energy to another.

All energy conversion processes will be inherently inefficient, meaning that in most cases we cannot realise the full potential of the unconverted energy.

We define efficiency as:-

$$\frac{\text{the amount of useful energy out}}{\text{the amount of energy put in}} \times 100\%$$

Some efficiencies (*):-

steam (railway) engines	10%
cars	20 - 25%
electric fire	~100%
gas central heating boiler	70 - 75%
oil central heating boiler	65 - 70%
UEA boiler	~87%
Power Station Boiler	90-92%
Open Coal fire	10%
Coal Central Heating	40-50%
Steam Turbine	45-50%

3.2 PRIMARY ENERGY -

The energy content of the energy resource when it is in the ground.

3.3 DELIVERED ENERGY -

The energy content of the fuel as it is delivered to the place of use.

3.4 USEFUL ENERGY -

The actual amount of energy required for a given function *IN THE FORM USABLE FOR THAT FUNCTION.*

3.5 PRIMARY ENERGY RATIO (PER):-

$$= \frac{\text{Primary Energy Content of fuel}}{\text{Delivered Energy content of fuel}}$$

EXAMPLES:-

Gas - 1.06
Oil - 1.08
Coal - 1.02

Thus for gas, 6% of the energy extracted is used either directly, or indirectly to deliver the energy to the customer. It will cover aspects such as the energy used in:-

- exploration
- making production platforms
- making pipelines
- pumping
- administration and retail of fuel
- fractionating/blending fuel

3.6 Appliance Efficiency (η)

At the consumers premises, appliances are not, in general 100% efficient in converting the fuel into a useful form of energy.

Thus (from 4.1 above):-

The efficiency of the appliance may be expressed as:-

$$\eta = \frac{\text{useful energy out (in form required)}}{\text{energy input to appliance (+)}}$$

in most cases, the efficiency will also be:-

$$= \frac{\text{useful energy}}{\text{delivered energy}}$$

3.7 FURTHER COMMENTS ABOUT EFFICIENCY

If we want 1 GJ or useful energy, how much energy must we dig from the ground if we require the energy as heat from as gas boiler with an efficiency of 70%?

Primary Energy Required

$$= \frac{1}{0.7} \times 1.06 = 1.51 \text{ GJ}$$

Be sure you understand this relationship, and why it is not:-

0.7 x 1.06

or 1.3 x 1.06

3.8 ENERGY EFFICIENCY

Energy Efficiency is the efficient use of energy.

IT DOES NOT NECESSARILY MEAN A SAVING OF RESOURCES.

e.g. Producing 20% more products for same energy input would not save energy overall even though it would reduce energy requirement per product.

Insulating a poorly heated house will increase the efficiency of using energy, but the savings in resources will be small - increased temperature - avoiding hypothermia is efficient use of energy.

3.9 ENERGY CONSERVATION

Energy Conservation is the saving of energy resources.

Energy Efficiency is a necessary pre-requisite for Energy Conservation

(remember Energy Efficiency does not necessarily mean Energy Conservation).

It is interesting to note the Government Office is termed

THE ENERGY EFFICIENCY OFFICE

3.10 OTHER DEFINITIONS OF ENERGY CONSERVATION

- **Industry/Commerce often consider Energy Conservation only as a saving in MONETARY terms**
- **The moral definition is the saving of resources. This often will not result in a MONETARY saving**
- **The so called Energy Conservation Grants to Industry in late 1970's early 1980's were not Conservation Grants at all, but Grants to encourage switching of fuels from oil to coal.**

3.11 LOAD FACTOR

The Load Factor is a measure of the utilisation of plant and is important in all Energy related topics. Thus a coal fired power station may have a capacity of 2000 MW which is a measure of the peak electrical output it can archive. On the other hand, there will be times when it is under maintenance, and/or not required to generate because the demand is low. Typically for a modern coal fired station this will be 70+%.

A nuclear power station may actually have a 100% load factor one year as it is running continuously, but because of statutory maintenance period which may last 60 days or so, the load factor in the following year will be much lower. Unlike fossil fired stations, nuclear stations are not readily capable of following demand and thus tend to be run for extended period. Load factors in any one year of 90+% have been achieved but at other times much lower, and average around 80+%.

Renewable generation has two separate aspects to consider. Not only is there the variation in demand, but more importantly there is the variation in the resource itself. In some cases, say on a windy day the supply for wind may be so high that it exceeds the local demand or capacity of interconnecting cables and some of the plant have to be shut down.

Typical Load Factors for renewable generation for 2006 are reproduced here from the Project Assignment Section. For details for other years see the Project Assignment Section

Load factors	2006
Onshore wind	27.4%
Offshore wind (from 2004 only)	27.2 %
Photovoltaic	8.1%
Hydro	34.8 %
Biofuels and wastes (excluding co-firing)	56.8%

Fig. 3.1 Current Load Factors for Renewable Generation

3.12 CALORIFIC VALUE

This is the Energy Content of the fuel per unit mass or unit volume. It represents the maximum amount of energy that can be extracted from a unit of the fuel.

There are two Calorific Values:-

lower calorific value

This is amount of energy derived by combusting a fuel when the products of combustion are emitted at temperatures in excess of 100^{o}C i.e. any water present is emitted as steam.

upper calorific value

This is amount of energy derived by combusting a fuel when the products of combustion are emitted at temperatures below 100^{o}C i.e. any water present is emitted as water vapour.

The difference between the two calorific values is about 5% (UCV > LCV)

3.13 SPECIFIC HEAT

This is the Energy required to raise the temperature of 1 kg of a body through 1 degree Celsius.

Space for notes

4. POTENTIAL OF ENERGY RESOURCES

4.1. CURRENT AND PROJECTED USAGE

Country	Energy Requirement		
		Population	Per Capita
World	**12.0 TW**	**6000 M**	**2.0 kW**
USA	**3.0 TW**	**300 M**	**10.0 kW**
Europe	**2.0 TW**	**350 M**	**5.7 kW**
UK	**0.3 TW**	**60 M**	**5.0 kW**

Projected Saturation Population in 2050 -- 10000 M

- If per Capita consumption averages current UK value
- Energy Requirement in 2050 = 50 TW i.e. 5×10^{13} W.
- If per Capita consumption reaches current USA value
- Projected Requirement in 2050 will be 100 TW i.e. 10 times current demand.
- Range of forecasts 20 - 100 TW with a likely value
- in range 30 - 50 TW (say 40 TW).

4.2 PROJECTED LIFESPAN OF RESOURCES

decades:-	oil, gas, ^{235}U (tar sands, oil shales)
centuries:	coal, geothermal, D - T fusion ^{238}U, ^{232}Th
millennia:	D - D fusion

With a project average consumption of 40 TW annual consumption will be:- 1.25×10^{21}

Compare this to the Current World *Proven* Reserves:-

Oil Reserves:-	**5×10^{21} J**
Gas Reserves:-	**4×10^{21} J**
Uranium:-	**1×10^{21} J**
Coal Reserves:-	**2.6×10^{22} J**
Uranium (Fast Breeder):-	**1×10^{23}**
Fusion (Deuterium):-	**1×10^{30}**

4.3 "RENEWABLE ENERGY RESOURCES"

Orders of magnitude only

Practically Achievable:-

10^{10} - Tidal (i.e. 1×10^{10} to 1×10^{11})

10^{11} - Geothermal; OTEC; Biomass; Wastes

10^{12} - Hydro; Wind; Waves

10^{13} – Solar

4.4 POTENTIAL RENEWABLE RESOURCES

	Theoretical	Practical	Realised to date (2004)	
	TW	**GW**	**GW**	
NON-SOLAR				
Tidal	3	50	0.25	France, Russia, China
Geothermal	30	60+	10.5 (Electrical)	Italy, Iceland, USA, New Zealand
			0.8 (Heat)	
SOLAR Direct				
Solar	30000	30000	1.8 (Electrical)	USA, Israel: Germany, third world
			0.02 (Active Thermal)	Does not include Passive Solar
SOLAR Indirect				
Wind	30	1000	47 GW	USA, Denmark, Germany, Netherlands, Spain ~ 1 GW in UK
Waves	3	30	0.01	UK, Norway, Japan
OTEC	30	300	0.001	USA
Hydro	30+	3000	650	USA, Brazil, Canada, Scandinavia, Switzerland, Malaysia etc.
Biomass/Wastes	300	1000	43 (electrical)	Various countries also increasing use of biofuels for transport which are currently included – e.g. Brazil - Bioethanol
			26 (Heat)	

Data for 2004 is based on actual amounts supplied according to IEA Statistics and assumed average Load Factors.

5. BARRIERS TO CONSERVATION

5.1 GOVERNMENTAL

- preference to support supply rather than conservation; partly because of long term historic memories, and consequential political overtones if they under estimate future supply requirements.
- where grants are made available, they are too late, and too restrictive - and will deter those who have made an investment in the past from doing so in the future.
- Is the method adopted in US during the Carter Administration a preferential one?
- lack of / or inadequate legislation to promote conservation (Latest Building Regulations do address some issues, but they are too late and there are many loop holes - so encourages minimum compliance rather than promoting conservation.)
- delays in decision making favour supply rather than conservation
- reluctance in past at Local Government Level to implement tougher measures - e.g. Building Industry who argue against such measures - Exceptions:- Southampton City Council; Milton Keynes, Woking..
- reluctance to promote strategies which could cost Government votes at next election (e.g. higher taxation on petrol etc.) - many measures take a period longer than lifetime of Government to become effective.
- enactment of legislation which is has loose or incorrect wording:- 1947 Electricity Act in UK. Conservation Bill in US in 1979.

5.2 VESTED INTERESTS

- manufacturing industries continuing to promote out of date products and/or energy wasteful products - or to give *Pseudo-Conservation Information*.
- retailers/developers promoting products on the capital outlay, or other attributes, and not energy consumption. Are ESCO's a way forward?
- competition between supply industries leads them to promote their products which may not always be the most energy conserving - e.g. off peak heating with electricity.
- scheduling of TV programs
- cowboy firms making unsubstantiated claims.
- preference to view Energy Conservation in terms of MONETARY saving rather than Resource saving.

5.3 ENVIRONMENTAL ISSUES

- incorporation of retrospective pollution controls usually INCREASES energy consumption.

e.g. Removal of SO_2 leads to:-

a) reduced efficiency at power stations, hence increased CO_2

b) as SO_2 is converted even more CO_2 is produced

c) Limestone required from Peak District etc.

d) Disposal of waste Gypsum

e) Additional Transport needed to power stations

f) FGD plant are large - comparable to size of power station (excluding cooling towers).

5.4 PHYSICAL LIMITATIONS

- laws of thermodynamics limit efficiency of energy conversion.
- climate affect energy consumption
- geological resources in a country will affect utilisation of energy.

e.g. it makes sense to use electricity for heating in Norway which has abundant hydro-electricity, but not in UK.

5.5 TECHNICAL PROBLEMS

- old buildings/appliances which have a long life so improvements in energy efficiency will take time to become effective.
- difficulty in making perfect machine
- difficulty in achieving high insulation standards in brick built buildings

5.6 SOCIAL ATTITUDES

- desire for greater thermal comfort. Comfort temperatures have risen over last 30 years.
- desire for greater mobility.
- desire for smaller households in larger and individual buildings (unlike many other European Countries).
- come to depend on reliability of energy supply (contrast situation in late 50's).
- purchasing larger and more energy wasteful appliances -e.g. tumbler dryers, freezers,cars etc. There is still a large potential growth in dish-washers.
- sliding back into old habits.

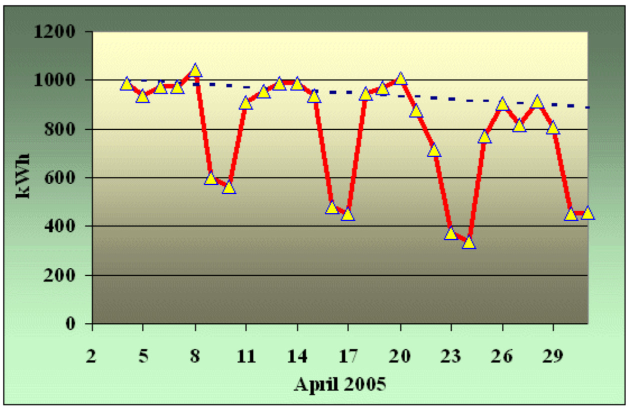

Fig. 5.1 UEA Switch off Campaign April 2005.

- disregarding notices/adverts designed to promote energy conservation.
- short memories - previous high costs of energy are forgotten when energy becomes cheap.
- energy conservation not often seen as important as direct investment even when the returns are much greater. Alternatively given lower priority than pleasure e.g. holidays etc.
- problem of comfort taking

5.7 ECONOMIC

- We expect a pay back for any investment in a short period. Is the idea of an Energy Service Company – a way around this?

  How would an ESCO work? Many Housing Developers are reluctant to invest in higher standard buildings as they see the capital cost rising and are concerned that potential buyers would not be prepared to pay the extra. The concept of an ESCO only became a legal possibility a few years ago after the relaxation of the 28 day rule.

  Suppose a developer was building houses and had considered including heat pumps as an energy conservation measure, but rejected them in terms of capital cost. The building would still have to conform to building regulations and require a condensing central heating boiler and radiators. The internals for the boiler, pipe work and installation may come to £5000, but a heat pump installation might be £10000. An ESCO would negotiate with the developer and suggest that he fit no internals and instead pay the saved capital cost (i.e £5000) to the ESCO who would then seek a loan for a further £5000 to pay for a heat pump installation. The ESCO would then negotiate with the householder saying that in the basic construction he would have been paying a given amount for energy, and this he would now pay to the ESCO. The ESCO would pay the actual bill to the utility which because of savings would be much less than normal, and the difference between what the householder pays the ESCO and the ESCO pays the utility company would building would pay back the loan and make the ESCO a profit for say 5 or so years. After that time the ESCO would move on to a new project and the householder would then benefit from much reduced energy bills.

  - In this way the developer has to charge no more for the house,
  - The householder pays no more initially for his energy but sees a reduction in the longer term,
  - The ESCO makes money through the contract,
  - The Environment wins.

  This concept is a bit like monthy contracts for mobile phones where those on such contracts often get the phones free.

- Assessment of an Energy project depends not only on the rate of return we expect (allowing for inflation etc.) which is related to the Discount Rate, but on how fuel prices are seen to change in the future.
- In the mid 1970's, it was predicted by many that the REAL price of energy would at least double by the end of the century. In practice energy is now cheaper in real terms than in 1970's despite recent rises
- Widely fluctuating fuel prices, and expectations on return can create a STOP GO attitude towards rational spending on Energy saving projects.
- In Industry, Energy Saving has to compete with increased productivity.

  Thus a new process which takes half the space of an old equivalent one, produces the same number of items in half the time would be favoured EVEN if it consumed 50-100% more in Energy (as labour costs would be reduced and profits increased because the price of Energy is TOO LOW).

- The choice of a particular Discount Rate (which is often dictated by Government) will load the dice in favour of a particular option if only Economics is used in decision making EVEN IF EXTERNAL ENVIRONMENTAL COSTS ARE INCLUDED.

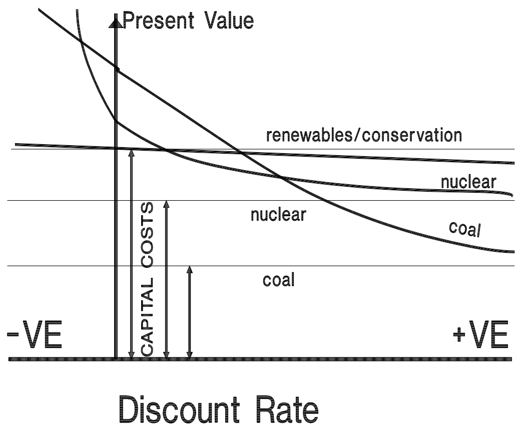

Fig. 5.2 Effect of Discount Rate on Economic Viability of Energy Projects

- High Discount Rates favour Coal
- Medium Discount Rates favour Nuclear
- Low/zero/negative Discount Rates favour Conservation and Renewables see Fig. 5.2

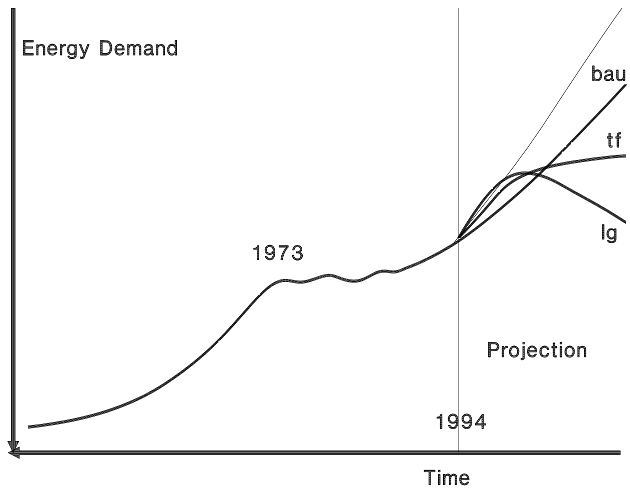

Fig. 5.3 Changing Energy demand with different strategies.

The following book is out of print, but several copies are available either in the Library or NKT as 3 copies.

Though it was written in 1970 the concepts covered are as important, and in many cases more so today

If you are doing Energy Conservation you should aim to read at least the first two chapters.

P. Chapman - Fuel's Paradise

If any of you frequent Second Hand Book Shops, copies often become available – please purchase any you see and NKT will endeavour to reimburse you.

6. THERMAL COMFORT

- The perception of thermal comfort is an individual thing as no two people will react the same in a given environment.
- In the ideal environment it has been shown by extensive research that if all individuals have the same clothing that when the temperature is at the optimum, 2.5% will find it too cold and 2.5% will find it too hot.
- Voting is normally done on the ASHRAE scale ranging from -3 for too cold to +3 for too hot.
- People who vote with values < -2 or > +2 are those who are at the extremes.
- The number of people voting at a particular values follows a Gaussian (normal) distribution which has its peak at a mean vote of zero.
- If we respond only to complaints from those who are feeling too cold or too hot then we are likely to find that more people will be dissatisfied as the curve will be shifted to hotter or colder end.
- Unfortunately, people who are too cold complain more actively than the other way, with the consequence that the temperature is often kept unnecessarily high.
- Remember that for every $1^{o}C$, the energy requirement rises by 8 - 10% (in UK).
- We need to be objective in any response to complaints by investigating the overall situation - not just the immediate problem of one or two complainants.

6.1 Thermal Comfort Theory

An individual's perception of thermal comfort depends on maintaining a balance between heat produced by body and heat losses:-

H - heat generated by body - depending on metabolic rate
R - heat lost through respiration
(two components - exhaust air is warmer than air taken in, AND
it is more moist - latent heat of evaporation)
E - heat lost through evaporation from skin (sweat)

So net heat generated by body is (Q)

$$Q = H - R - E$$

To maintain a balance this value of Q must loss by radiation and convection from the clothing

i.e. $$Q = H - R - E = Q_r + Q_c \qquad ......(1)$$

where Q_r is heat lost by radiation
Q_c is heat lost by convection

Expressions can be derived for each of the above quantities - some are very complex, but none need concern us.

NOTE: The additional handout is ONLY for those who are mathematically inclined and would like to know a little more about the background. Tables have been computed to allow us to work out estimates of thermal comfort without this elaboration.

If H becomes too large for heat losses, then the body will overheat and this is compensated by increasing evaporation from the skin.

If the body becomes cold, the body responds by shivering which causes the skin to roughen and the surface air-resistance, and hence resistance to heat transfer to increase.

6.2 Factors affecting Thermal Comfort

a) the air temperature
b) the mean radiant temperature
c) the relative humidity
d) the level of clothing
e) the activity level
f) the air velocity

The mean radiant temperature is measured with a Globe Thermometer and is related to the exchange of heat between a person and his/her surroundings.

This is a 3D problem and is related to the angle each surface in a room subtends at the point of measurement. Thus near a window, the window will subtend a much larger angle than the wall remote from the window.

Since the internal surface of the window is much colder than the internal surface of the walls, a large expanse of window will make a person feel colder.

As an approximation, the AVERAGE MEAN radiant temperature within a room may be estimated by the following

$$\frac{\Sigma\text{(surface areas x surface temperatures)}}{\text{total surface area}}$$

The theoretical basis of Thermal Comfort was developed by Fanger in a book entitled "Thermal Comfort"

Some chapters are very readable and descriptive about the experiments conducted others are mathematical!

Tables have been produced to simplify analysis.

6.3 Thermal Comfort Experiments

Experiments were conducted in which all subjects were clothed identically and placed in a controlled environment where their activity level was closely monitored.

Periodically they were asked to respond to a number of questions including how hot or cold they felt.

This provided the necessary link between the physical parameters and the subjective perception.

By constructing charts and tables, the analysis for a particular environment is now relatively easy. The tables are for a standard 50% humidity and the mean radiant temperature equalling the air temperature.

1) select table for appropriate metabolic rate.
2) select appropriate clothing level sub-table
3) now read of value corresponding to air (dry-bulb) temperature
4) and wind speed.

This value is the basic value and is the Predicted Mean Vote for a large number (100+) individuals. At this stage, no allowance is made of humidity or mean radiant temperature.

5) Now use the Humidity correction chart which gives the correction for each 1% variation in humidity from 50%
6) Repeat for the Mean Radiant Temperature Correction chart i.e. for each 1^{o}C that the MRT differs from the dry bulb temperature.
7) Apply these corrections to the basic value to obtain the corrected PMV (predicted Mean Vote).
8) Use further chart to estimate proportion of people likely to be dissatisfied with thermal environment.

6.4 THERMAL COMFORT - EXAMPLE

An office is 3m x 3m x 3m high with an external wall which is has a large 2m high window on the full width of the external wall - (single glazing) and North facing.

The outside temperature is 0^{o}C while the internal air temperature is 19.5^{o}C through out the building and the relative air-temperature is 50%

The office worker wearing clothing with a CLO value of 1.0 and has an activity level of 60 kcal hr^{-1}m^{-2} complains of being too cold.

You measure the average mean radiant temperature at worker's desk to be 17^{o}C, 18.5^{o}C on the other size of the room, and 20^{o}C in a similar south facing room. In What action would you take?

1) Need to estimate AVERAGE mean radiant temperature
2) Estimate Predicted Mean Vote
3) Consider Strategies

It can be assumed that air velocity in room is negligible.

So selecting appropriate section of table for activity level and clothing level

Air Temp	
18	-0.75
20	-0.32

By linear interpolation,

Predicted Mean vote = -0.75 + (19.5 - 18)/(20-18) * 0.43 = - 0.43

====

Now estimate correction for MRT difference

At 50 kcal hr^{-1}m^{-2} correction is + 0.12
At 100 kcal hr^{-1}m^{-2} correction is + 0.06

So at 60 kcal hr^{-1} m^{-2} correction will be

+0.12 - 0.06/5 = **0.11**

In North facing Office near window

PMV = - 0.43 - 0.11 * (19.5 - 17) = - 0.69

on other side of office

PMV = - 0.43 - 0.11 * (19.5 - 18.5) = - 0.54

in south facing office

PMV = - 0.43 - 0.11 * (19.5 - 20) = - 0.37

ACTION:

By Law thermostat cannot be set above 19^{o}C, and air temperature is already above this (from incidental gains). Moving the desk to the other side of the room would help or better still to a south facing office.

By complaining, the office worker must be voting < -2, and yet the mean vote is only slightly negative. This suggests that person always feels cold and should be encouraged to wear an extra sweater. Increasing the CLO value to 1.25 will increase the vote by about 0.3.

6.5 COMPUTATION of *AVERAGE MEAN* RADIANT TEMPERATURE

Strictly speaking this should be:-

Mean Temporal, Mean Spatial Mean Radiant Temperature!

Example: An office is 3m x 3m x 3m (typical of UEA), and windows are 2m high and full width of one wall. What is MRT if internal surface temperature of windows is 8^{o}C, and that of the external wall is 18^{o}C. The air-temperature is 20^{o}C.

[Note: We shall be considering question of internal surface temperatures in next lecture].

There are 5 internal surfaces (3 walls and ceiling and floor) at internal air-temperature i.e. 20^{o}C.

So MRT =

$$\frac{5 \text{ x } 3 \text{ x } 3 \text{ x } 20 + 1 \text{ x } 3 \text{ x } 18 + 2 \text{ x } 3 \text{ x } 8}{6 \text{ x } 3 \text{ x } 3} = \frac{334}{18} = 18.56\,^{\circ}\text{C}$$

With double glazing, the internal surface temperature of the windows would rise to around 14^{o}C and the MRT to 19.44^{o}C. [check this out as an exercise].

From the previous example, we saw that a rise of 1^{o}C in MRT will improve predicted Mean Vote by around 0.11, so this will be the improvement through double glazing in this room. Alternatively we could reduce the air temperature slightly to get the same equivalent comfort level.

Note: Double Glazing sales people rarely recognise this additional benefit of double glazing.

Double glazing has three benefits:-

- reduces loss through windows by half
- enables air temperature to be reduced to maintain same comfort level, and thus REDUCES loss through other components.
- will often reduce air-exchange rate by as much as 0.3+

6.6 THERMAL COMFORT - SUMMARY

Thermal Comfort measurements may be used to assess a given environment and are a useful additional aspect of Energy Management.

The level of comfort may be predicted using Fanger's Equations, however, you should note the following:-

It is difficult to accurately assess metabolic rate, and there is a tendency to underestimate value for people who are seated unless they have been in the particular Environment and at the particular activity level for at least an hour.

Manual use of the charts gives a value approximately 0.2 or so higher than the computer prediction. This was discovered in a cross check, and it is believed that one of the lengthy equations in Fanger's Book from which the computer program was developed has an incorrect sign. This is being investigated.

Fanger's Theory strictly applies only to individuals having the same clothing, but taking the mean values of a large number of votes should give the same as Fanger (but for the above problems).

If actual votes are available then use can still be made of Thermal Comfort Tables or the computer to assess the effects of changes in the Environmental Conditions on the mean VOTE.

Rarely is actual thermal comfort data used in Energy Management Decisions - responses are usually made for those who feel too cold without identifying the real problem

THERMAL COMFORT THEORY IS COVERED IN THE BOOK "THERMAL COMFORT" BY FANGER.

Several chapters dealing with the experimentation are very readable, and cover the aspects of thermal comfort more fully than in this course.

A HEALTH WARNING !

OTHER CHAPTERS IN FANGER ARE VERY MATHEMATICAL, BUT THIS HANDOUT SUMMARISES THE BASIC THEORY OF THERMAL COMFORT BY FANGER FOR THOSE WHO ARE INTERESTED.

IT MAKES SEVERAL SIMPLIFYING ASSUMPTIONS, BUT EVEN SO THE EQUATIONS ARE SOMEWHAT COMPLEX.

THIS HANDOUT IS INTENDED AS ADDITIONAL READING - ONLY FOR THOSE WHO ARE MATHEMATICALLY INCLINED IN PURSUING THE TOPIC FURTHER OR AS A GUIDE TO THOSE WHO WISH TO LOOK AT MATHEMATICAL SECTIONS IN FANGER'S BOOK

YOU WILL NOT BE ASKED TO REPRODUCE ANY OF THIS NEXT SECTION IN THE EXAMS.

THERMAL COMFORT

- SOME guidance on Mathematical Chapters in Fanger's Book " Thermal Comfort"

Variables affecting thermal comfort are:-

i) heat produced by body ~ metabolic rate
ii) clothing
iii) air temperature
iv) mean radiant temperature
v) humidity (vapour pressure of water)
vi) relative air velocity

Thermal comfort is covered by the Heat Balance Equations:-

$$H - R - E = Q = Q_R + Q_C \quad \text{.....................(1)}$$

where H is heat produced by body

Q_R and Q_C are the heat lost from clothing by radiation and convection

Q = heat flow through clothing

R and E are the heat lost through perspiration (dry and latent)
and heat lost through evaporation of sweat etc.

Expressions can be derived for each of above quantities for instance, the heat flow through the clothing (i.e. the middle part of equation (1) is conductive and of the form:-

$$Q = \frac{A(t_s - t_{c\ell})}{R_{c\ell}} \quad \text{watts} \quad \text{...........................(2a)}$$

where t_s and t_c are the temperatures of the skin and clothing respectively,
A is the area of the nude body,
and R_{cl} is the thermal resistance of the clothing.

Some of the relationships for the quantities in equation (1) are complex and can only be found empirically. However, once found they can be substituted into equation (1). The full equation is awkward to use and for most purposes, the approximate form may be used:-

LHS of equation (1) =

$$H - R - E = 0.53\frac{M}{A} + 0.003 p_a + 6.92 \quad \text{.........(2b)}$$

RHS of equation (1) =

$$Q_R + Q_c = (3.95 \times 10^{-8}(T_{c\ell}^4 - T_{mrt}^4) + (t_{c\ell} - t_a)) f_{c\ell} \quad \text{.................(2c)}$$

This approximate form of the full equation is valid if the ***mechanical*** efficiency of the body is zero, which it is in most cases. It is only non- zero if the person is climbing a hill or stairs.

Here: -

M	is the metabolic rate	p_a	vapour pressure of water in ambient air
t_a	air temperature	T_{cl}	Absolute Temperature of surface of clothing
T_{mrt}	Mean radiant Temperature (absolute)	f_{cl}	area of clothed body to nude body
h_c	coefficient of heat transfer by convection		

Values of **M/A** (i.e. the Metabolic Rate) are tabulated for various types of activity,
e.g. sleeping 40 Wm^{-2},
seated 60 Wm^{-2},
standing still, 70 Wm^{-2}.

Note: in the tables from Fanger 1970 on the separate sheets, the values are given in kcal hr^{-1} m^{-2}.
[NOTE: 10 kcal hr^{-1} m^{-2} = 1.163 wm^{-2}]

In the equations (2), the quantities p_a, t_a, and T_{mrt} may be measured directly, t_s can be found from the empirical relationship:-

$$t_s = 35.7 - 0.032\frac{M}{A}(1 - \eta)$$

where η is the mechanical efficiency and h_c is given by:-

$$h_c = 2.38(t_{cl} - t_a)^{0.25} \quad \text{for } < 0.1\ ms^{-1}$$

and $h_c = 12.1$ for $> 0.1\ ms^{-1}$

f_c varies from 1.0 for the nude body to 1.4 person clad in heavy outdoor clothing.

Finally, t_c can be found by iteratively solving the RHS and middle parts of equation (2, i.e. 2a and 2c). In theory, t_c could also be obtained from the first two parts of the equation (1, or 2a and 2b), but it must be remembered that the L.H.S. contains several approximations and greater precision is likely if the equations 2a and 2c are used.

The heat balance equations must be satisfied if a person is to survive and indeed the regulatory systems within the body respond to cope with adverse conditions e.g. sweating (to increase loss by evaporation) when hot or shivering (to increase thermal resistance of the skin) when cold. The equation, however, does not indicate whether the person is comfortable and indeed the more the regulatory systems have to operate with adverse conditions, the greater will be the feeling of discomfort. To incorporate such feelings, a physiological scale of thermal comfort perception must be considered. There are several such scales but the common one is the ASHRAE scale which goes from **-3** for extreme cold to **+3** for extreme heat.

Fanger conducted a large number of investigations in which he investigated the variation in mean vote for a large number of subjects with air temperature. All subjects had the same clothing (0.6 clo) and the relative humidity was kept at 50%, and the mean radiant temperature was equal to that of the air temperature.

Activity Level	Wm^{-2}	(kcal hr^{-1} m^{-2})	Mean Vote Y
Seated	58	50	$Y = -8.47 + 0.33t_a$
Low	93	80	$Y = -3.64 + 0.18t_a$
Medium	123	(106)	$Y = -3.36 + 0.l7t_a$
High	157	(135)	$Y = -4.16 + 0.27t_a$

Y is a prediction of the Mean Vote of comfort by a large number of respondents
It is now necessary to combine these equations in some way with the heat balance equation.

Let L be the Heat load caused by Temporary imbalance in the heat balance equation

i.e. $\mathbf{L = H - R - E - (Q_R + Q_C)}$ ....(3)

We now examine the variations in both L and Y for small changes in t_a. Typically we shall use finite differences, and noting that.

$$\frac{\delta Y}{\delta L} = \frac{\delta Y}{\delta t_a} \cdot \frac{\delta t_a}{\delta Y}$$

we can evaluate values of $\frac{Y}{L}$ for different values of $\frac{M}{A}$

A simple linear regression on the data gives:-

$$\frac{\delta Y}{\delta L} = 0.092 - 4.8 \times 10^{-4} \frac{M}{A} \qquad \text{..............................(4)}$$

Alternatively, Fanger, reckons that the following exponential is more realistic;

$$\text{i.e. } \frac{\delta Y}{\delta L} = \left(0.352\, e^{-0.042\frac{M}{A}} + 0.032\right) \qquad \text{................(5)}$$

We may integrate either equation (4) or equation (5) to obtain an expression for Y in terms of L. For compatibility with Fanger, we choose equation (5), and substituting for L in equation (3) and combining with equations (2) gives an estimate for Y if the approximations noted relating to equation (2) are applied :-

$$\mathbf{Y} = \left(0.352\, e^{-0.042\frac{M}{A}} + 0.032\right)\left\{0.53\frac{M}{A} + 0.003P_a + 6.92 - \left[3.95 \times 10^{-8}(T_c^4 - T_{mrt}^4) + h_c(t_c - t_a)f_{cl}\right]\right\}$$

Tables exist to evaluate **Y** at 5O% R.H., and $T_{mrt} = T_a$. When these latter conditions are not true corrections may be made using the appropriate diagrams

7. CONSERVATION POSSIBILITIES.

- **Technical**
  - **Energy Conversion**
  - **End use of energy**
- **Education**
- **Energy Management**

Technical Measures will have limited impact on energy consumption if people are not educated to use energy wisely.

Energy Management is a key aspect in energy conservation

A good Energy Manager will:-

- **Assess** Energy Demand - record keeping
- **Analyse** Energy Demand - examine trends relating to physical factors
- **Advise** of technical and other methods to promote energy conservation
- **Advertise** and publicise ways to save energy
- **Account** for energy consumed

OTHER POINTS

- **Significant saving are possible by reducing waste in conversion of energy to secondary fuels**
- **Effective Energy Conservation and Environmental Legislation may well see a rise in electricity consumption in the short term.**
- **promotion of heat pumps**
- **industry switching to more efficient electrically driven processes**
- **move towards electric cars.?????**
- **Hydrogen ????**

A Paradox

Despite in efficiencies in electricity generation, heat pumps and hydrogen offer significant opportunities for energy conservation and CO_2 emission reduction.

So effective promotion of energy conservation could lead to an increase in electricity consumption.

8. Summary of Consumption in UK (1993-2008) - per capita consumption

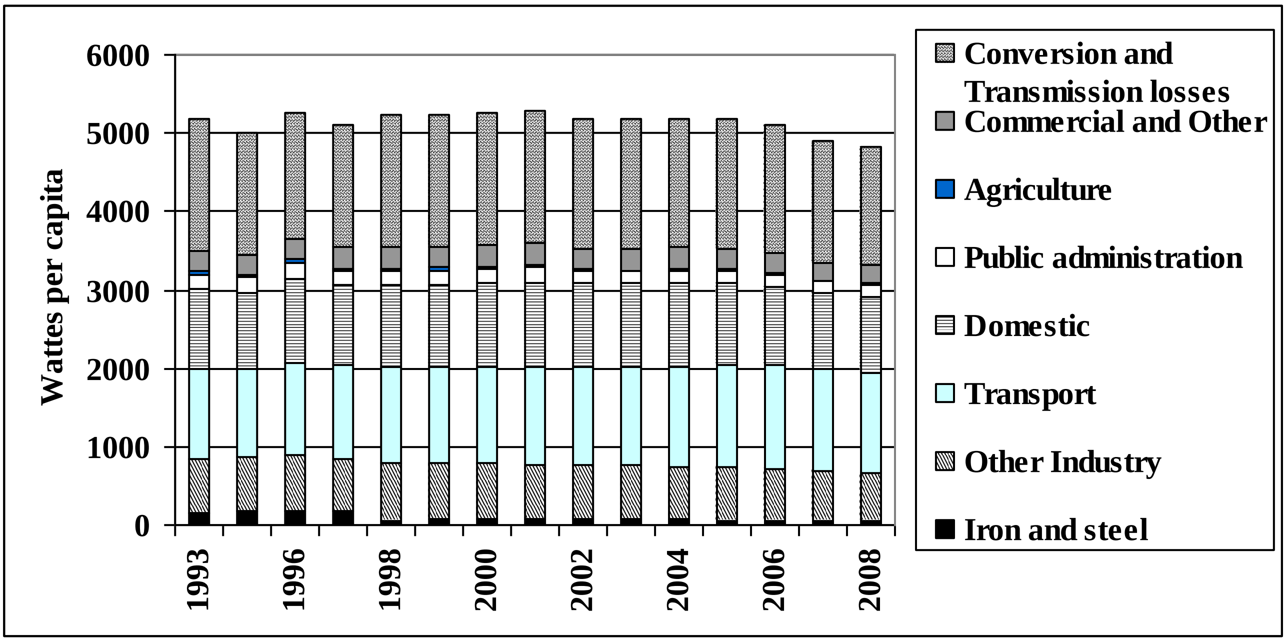

Fig. 8.1 Variation in Energy Consumption 1993 – 2008 – see table 8.1 for detailed information

Note:

1. Rate of Population increase has increased from
2. Overall UK consumption has remained nearly static although has shown a reduction in last two years.
3. Variations in Domestic, Administration, and Commercial are largely due to climatic effects.
4. Industry overall has declined slightly
5. Conversion losses declined
5. Transport demand has risen by 11.4% since 1993 although it has now declined from a peak of 15% in 2006.

Table 8.1 UK Per Capita Consumption in watts for different sectors

	Watts per Capita															annual % change			
	1993	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	1993-2008	1993-2000	2000-2005	2005-2008
Populations (thousands)	57714	58025	58164	58314	58475	58684	58886	59114	59322	59,557	59,846	60,209	60,587	60,975	61,383	0.41%	0.29%	0.45%	0.65%
Iron and steel	159	174	181	177	61	86	86	86	71	68	64	61	63	59	54	-6.95%	-8.41%	-6.64%	-3.98%
Other Industry	678	685	706	676	725	698	695	692	705	693	671	678	657	629	608	-0.72%	0.35%	-0.49%	-3.57%
Transport	1142	1138	1180	1193	1219	1238	1247	1234	1239	1260	1281	1302	1314	1309	1272	0.72%	1.26%	0.87%	-0.77%
Domestic	1039	967	1085	1008	1047	1043	1057	1090	1069	1063	1078	1040	1003	963	987	-0.34%	0.25%	-0.32%	-1.73%
Public administration	186	193	202	193	185	190	183	182	158	150	160	159	155	146	150	-1.42%	-0.23%	-2.77%	-1.92%
Agriculture	31	30	32	30	31	29	27	29	25	21	20	22	20	20	20	-2.88%	-1.95%	-4.01%	-3.13%
Commercial and Other	256	259	274	274	273	269	276	288	261	268	270	267	261	217	220	-1.01%	1.08%	-0.66%	-6.25%
Conversion and Transmission losses	1693	1555	1601	1554	1690	1684	1678	1672	1666	1649	1635	1649	1628	1552	1503	-0.79%	-0.13%	-0.35%	-3.04%
Total Direct Energy Use	**5184**	**5003**	**5261**	**5106**	**5231**	**5236**	**5249**	**5272**	**5194**	5172	5179	5178	5101	4895	4814	-0.49%	0.18%	-0.27%	-2.40%
Non energy use					281	280	279	278	277	268	270	267	261	217	220		-0.88%	-0.88%	-6.25%
Total Primary Demand					**5512**	**5516**	**5528**	**5550**	**5471**	5440	5449	5445	5362	5112	5034		-0.30%	-0.30%	-2.58%

9 CONVENTIONAL GENERATION OF ELECTRICITY

9.1 Introduction

There are major losses in delivering energy to point of end use. The majority of this is accounted for by conversion of fuel into electricity.

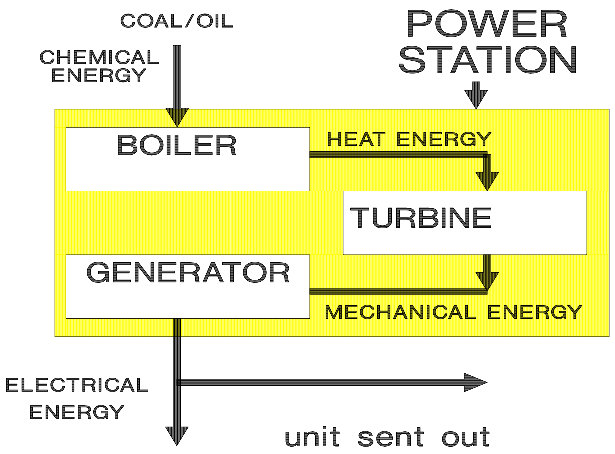

Fig. 9.1 Summary of Energy Conversions in a Power Station

Typically only 35-37% of energy in fuel in a conventional coal-fired power station is output as useful electricity, a further 3% is lost in transmission. Gas stations can reach 46-56% efficiency.

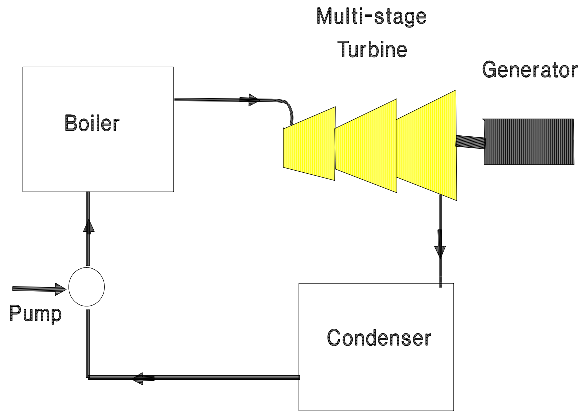

Fig. 9.2 Typical configuration for generation of electricity showing power circuit.

Supply of electricity

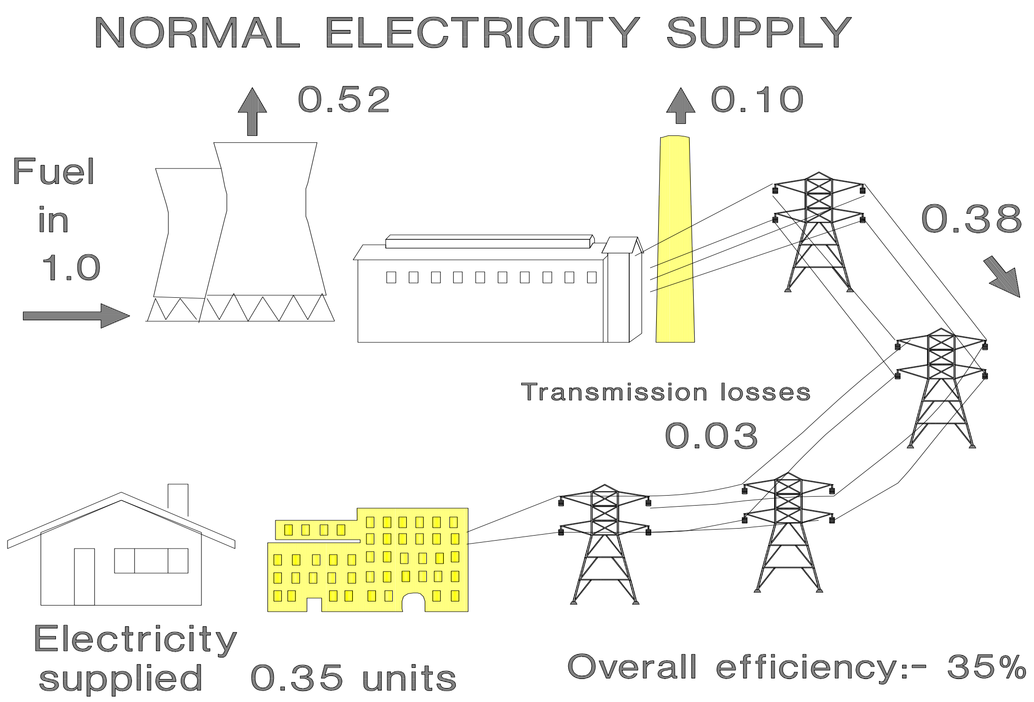

Fig. 9.3 Conventional Generation of Electricity

- Why not use the heat from power station? - it is typically at 30^{o}C?
- This too cold for space heating as radiators must be operated much hotter than this otherwise they will not be able to supply sufficient heat (alternative is to have radiators the size of walls).
- What about fish farming - tomato growing? - Yes, but this only represent about 0.005% of heat output.
- Problem is that if we increase the output temperature of the heat from the power station we get less electricity.
- Does this matter if overall energy supply is increased? 1947 Electricity Act blinked our approach for 35 years into attempting to get as much electricity from fuel rather than as much energy.

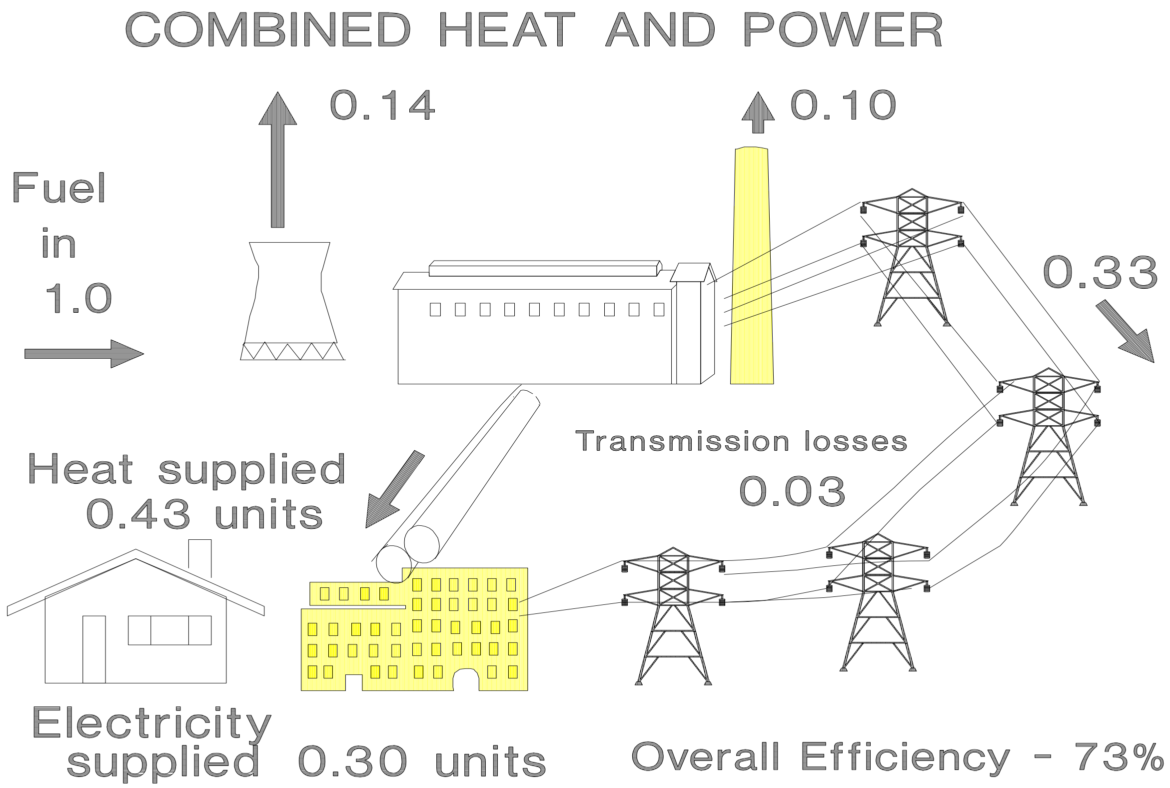

Fig. 9.4 Generation of Electricity using Combined Heat and Power

In this situation, the waste heat from the power station is rejected at about 90^{o}C and can be piped to homes etc. for space heating.

Though the amount of electricity has reduced, the overall amount of useful delivered energy has increased substantially.

To understand what is going on we need to consider thermodynamics.

10. THERMODYNAMICS

10.1 Introduction

Classical thermodynamics is an exact science and forms a fundamental requirement in the understanding of processes in many branches of science.

The beginnings of thermodynamics can be traced to the late eighteenth century when attempts were made to reduce the steam consumption of the early beam engines of the Newcomen type (Fig. 10.1). It was Watt's idea to condense the steam in a vessel other than the working piston that led to dramatic improvements in the performance of mechanical devices (Fig.10.2).

The improvement in the fuel consumption lead engineers and scientists to consider whether or not the fuel consumption could be reduced indefinitely. If the answer was no, then what laws governed the processes and what theoretically was the minimum fuel consumption for a given amount of work? In providing the answers, the science of thermodynamics was born.

It must be stressed that the initial considerations were for the extraction of the greatest amount of work or power from any process and not for the production of work at the greatest overall <u>useful</u> efficiency.

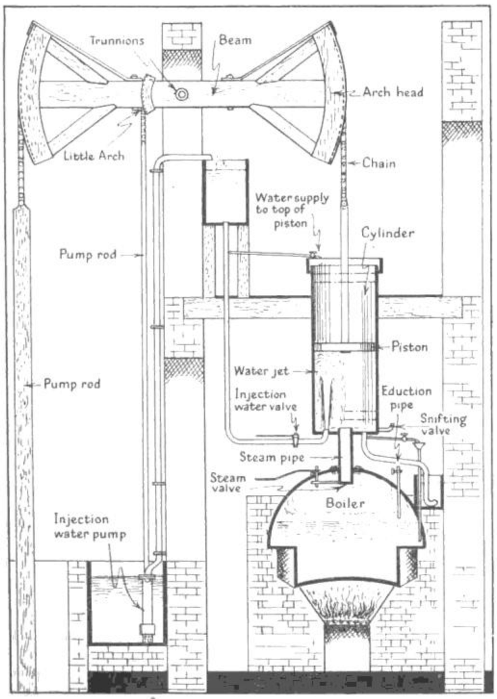

Fig. 10.1 The original steam engine - Newcommen

Even in the 196O's this philosophy existed in the design of power stations. Heat at low temperature was considered as being useless, and in the production of power we still see that even the most efficient methods reject vast quantities of heat at low temperatures which, until the recent so called energy crisis, were considered as being virtually useless. Students in Engineering Thermodynamics were taught that work was all important and that waste heat was useless, particularly as one could heat buildings readily by the burning of fossil fuel.

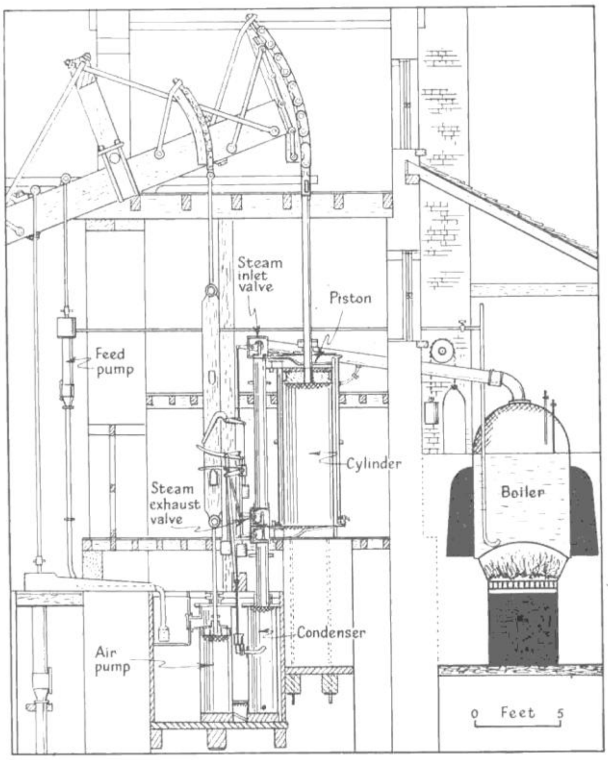

Fig. 10.2 Watt's Steam Engine increased efficiency of Newcommen Enegine by a factor of 4.

In the early days of the industrial revolution new ideas could be built and tested to see if they worked. In many cases the designs resulted in failures. In the current financial climate we cannot afford to advance our standards of living by costly failures, and although the testing of prototypes is absolutely necessary, the early designs will have invoked thermodynamics in the prediction of performances, and many inefficient processes can be eliminated before construction commences.

If, for instance, we have a plentiful supply of solar energy as we will have in many of the underdeveloped countries it would be possible at least in theory to estimate how much steam could be produced and at what temperature and pressure. From these latter two we can predict that maximum total power, work or electrical energy that can be produced by this steam.

We could, of course, have produced this steam by the combustion of a fossil fuel, and once again thermo-dynamics would enable us to predict the likely quantities and nature of steam or electricity.

The reader may think that this introduction is becoming over concerned about the production of power as have most of the texts on classical engineering thermodynamics been in the past.

It is, however, necessary to consider the uses of both the produced power and the hitherto 'useless' waste heat. The production of power is of importance even in considerations of the simple heating of buildings since the input of a small amount of power can lead to the transference of large quantities of heat into a building. In other words the input of one unit of energy in the form of power can lead to the transference of several units of energy in the form of heat, into a building. This apparent 'something for nothing' can only be explained with reference to applications of the Second Law of Thermodynamics.

Clearly thermodynamics is of importance in any consideration of the energy production whether it be in the form of burning of fossil fuels or in the use of alternative energy sources.

10.2 The discovery of the laws of thermodynamics

There are four laws of thermodynamics, namely the zero'th, first, second and third. Of these the first and second are of greatest importance to us, while the zero'th is of importance, as unless it were true, we should not be able to measure temperature.

Chronologically the first aspects relating to the Second Law of Thermodynamics were put forward by Carnot in 1824. Before Carnot it was appreciated that one had to put heat in to get work out, and the question which required solution was 'What laws governed the Conversion of heat into work?'

Carnot perceived that TEMPERATURE provided the key and he utilised the method of arguing by analogy. He likened the work produced for heat to that produced when water flows from a high level to a lower level to a low level. Could not high and low temperature be the counter- parts of the high or low levels? This analogy is indeed correct and is now embodied in what is now known as the second law of Thermodynamics.
In one respect Carnot was incorrect and this arose because he used the water analogy. In the case of water, the same quantity of water flows out at the low level as entered at the high level. In the case of heat it is now known that less heat flows out at low temperatures. In Carnot's day even the best engines had heat inflows and heat outflows which differed by less than 1O%, and such a difference would hardly have been detectable.

It was in 185O that Joule discovered that the 'lost' heat had "turned into" work and this law is now known as the First Law of Thermo-dynamics. This law is the one which most perpetual motion machines contravene. The remainder contravene the second law.

The remainder of this document is given to an elementary introduction to the thermodynamics but for further information it is suggested that the reader consult an appropriate text on thermodynamics.

10.3 KEY POINTS of THERMO-DYNAMICS:

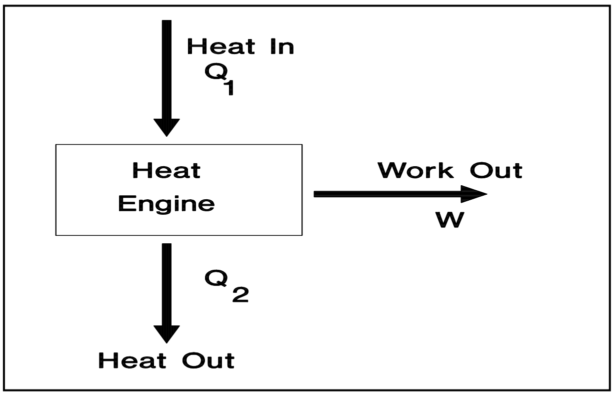

Fig. 10.3 Schematic Diagram of a Heat Engine converting Heat to Work

1: FIRST LAW equates the algebraic sum of the work done by a system to the algebraic sum of the heat transfers to/from the system.

- Heat into system is "positive":
- Heat rejected is "negative"
- Work done BY system is "positive":
- Work done on system is "negative"

i.e.. $W_1 + W_2 + \ldots\ldots = Q_1 + Q_2 + \ldots\ldots$

In a typical system $W = Q_1 - Q_2$

2: SECOND LAW is more restrictive than the FIRST LAW and states that when WORK is obtained from heat, the conversion process must ALWAYS reject heat. This limits the theoretical (or CARNOT) efficiency.

3) Efficiency is defined as $\dfrac{\text{work out}}{\text{heat in}} \times 100$

Since heat flow is proportional to temperature we can replace heat flows by temperature.

i.e. $\eta = \dfrac{T_1 - T_2}{T_1} \times 100$

This the theoretical or Carnot efficiency.

4) Practically, the efficiency will always be less than the Carnot Efficiency. To obtain the "real" efficiency we define the term *Isentropic Efficiency* as follows:-

$$\eta_{isen} = \frac{\text{actual work out}}{\text{work output from Carnot Cycle}}$$

Thus "real" efficiency $= \eta_{carnot} \times \eta_{isen}$

5) A power station involves several energy conversions. The overall efficiency is obtained from the product of the efficiencies of the respective stages.

EXAMPLE:

In a coal fired power station like DRAX, the steam inlet temperature is 566°C and the exhaust temperature to the condenser is around 30°C. The combustion efficiency is around 90%, while the generator efficiency is 95% and the isentropic efficiency is 75%. If 6% of the electricity generated is used on the station itself, and transmission losses amount to 5% and the primary energy ratio is 1.02, how much primary energy must be extracted to deliver 1 unit of electricity to the consumer?

Carnot efficiency $= \dfrac{(566 + 273) - (30 + 273)}{566 + 273} = 63.9\%$

so overall efficiency in power station:-

= 0.9 x 0.639 x 0.75 x 0.95 x 0.94 = 0.385

(combustion loss | carnot | isentropic | generator | station)

allowing for transmission losses and the primary energy ratio, 1 unit of primary energy will produce:-

$\dfrac{1 \times 0.385 \times 0.95}{1.02} = 0.359$ units of delivered energy

i.e. 1 / 0.359 = 2.79 units of primary energy are needed to deliver 1 unit of electricity.

If we could increase T_1 or decrease T_2 then we could improve the Carnot Efficiency.

WE CANNOT change T_2, but we could increase T_1. However, the properties of water/steam means that there is an upper limit of around 600°C.

We can improve matters by the use of combined cycle gas turbine stations CCGTs.

10.4 Heat Pumps

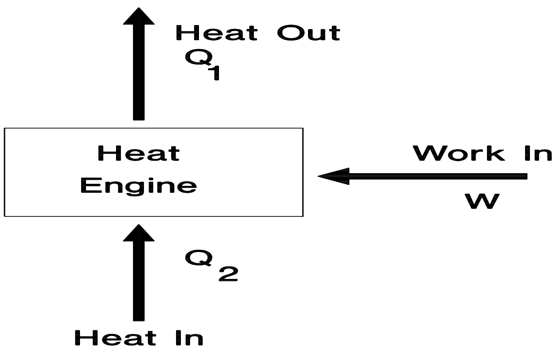

Fig. 10.4 Schematic Representation of a Heat Pump. NOTE: it is a reversed heat engine. **IT IS NOT A REVERSED REFRIGERATOR.**

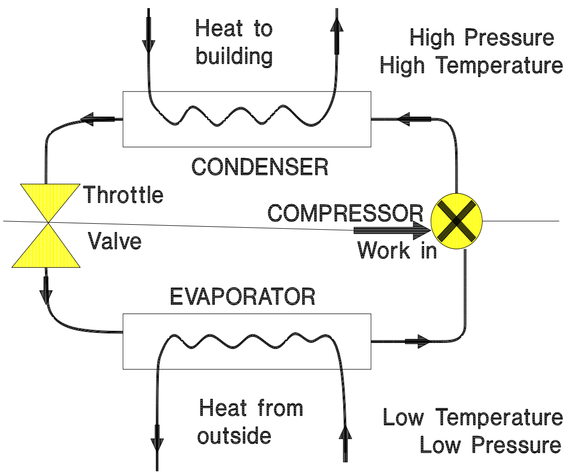

Fig. 101.5 A typical Heat Pump showing components

A heat pump consists of four parts:-

1) an evaporator (operating under low pressure and temperature)
2) a compressor to raise the pressure of the working fluid
3) a condenser (operating under high pressure and temperature)
4) a throttle value to reduce the pressure from high to low.

Low temperature heat from an external source (e.g. air, ground, or water) is pumped through the evaporator (a contra-flow heat exchanger). In this, the refrigerant is under low pressure typically 0.1-1.0 bar, and enters as a liquid but soon boils as it passes through. On leaving the evaporator, the fluid is entirely a gas but still under low pressure. The heat transfer from to the refrigerant is essentially at constant temperature (as the fluid is boiling) and therefore efficient. For a heat pump for a house using the ground as the heat source the temperature will typically be around 0^{o}C.

The fluid is now compressed to typically one bar in a compressor (usually a reciprocating one for small devices or a rotary one for large devices). The outlet gas is now under high pressure (typically 3-7 bar) and at high temperature. For a domestic application, this high temperature will typically be around $50+^{o}$C (for hot water systems it is likely to be somewhat higher (around 65^{o}C), and for hot air systems, rather lower.

Heat is released from the refrigerant in the condenser which is once again a contra flow heat exchanger and transferred to the heat medium to heat the building. The refrigerant condenses back to a liquid at constant temperature.

Finally, the high pressure condensed liquid is expanded through a throttle valve to complete the cycle. This expansion is unrestricted, and an obvious inefficiency, but the amount of work that could be recovered here is small (as the volume change in a liquid is small on expansion) that technically and economically it would not be feasible to utilise this work. (Indeed it affect the overall practical COP very little).

If Q_1 is the heat rejected to the building,, Q_2 is the amount of heat extracted from the source, and W is the work input, then by the FIRST LAW:-

$$Q_1 = Q_2 + W$$

$$\text{i.e. } COP = \frac{Q_1}{W} = \frac{Q_1}{Q_1 - Q_2} = \frac{T_1}{T_1 - T_2}$$

If the heat pump has a heat source as the ground at 0^{o}C and supplies heat at 50^{o}C, then the Coefficient of Performance COP is given by:-

$$COP = \frac{(273 + 50)}{(273 + 50) - (273 + 0)} = 6.46$$

Note the temperature used in the equation must be in Kelvin

Thus, theoretically, for every one unit of energy we put in we get 6.46 units out. Practically, we can achieve about 50% of the theoretical COP, i.e. about 3.23 in this case.

The heat pump allows us to work with the Laws of Thermodynamics and extract heat which would otherwise be unusable.

If we have an electrically driven heat pump, even allowing for the 3:1 inefficiency in generation, we can more than recover the "lost" energy in the power stations.

i.e. we need only 3 / 3.23 = 0.93 units of primary energy to supply 1 unit of useful energy as heat.

in the best alternative (using a condensing gas boiler), we would require:-

1 / 0.9 units = 1.11 units (i.e. a heat pump would save over 16% in the case and considerably more with other types of heating

10. 5. COMBINED CYCLE GAS TURBINE STATIONS

A combined cycle gas turbine station overcomes the problem in steam stations that the temperature cannot be raised too high because of the properties of water/steam. Instead gas is compressed and burnt at a significantly increased temperature in a gas turbine, which by itself is not that efficient. However, by using the waste gases to raise steam (replacing the conventional boiler), the overall efficiency is greatly improved.

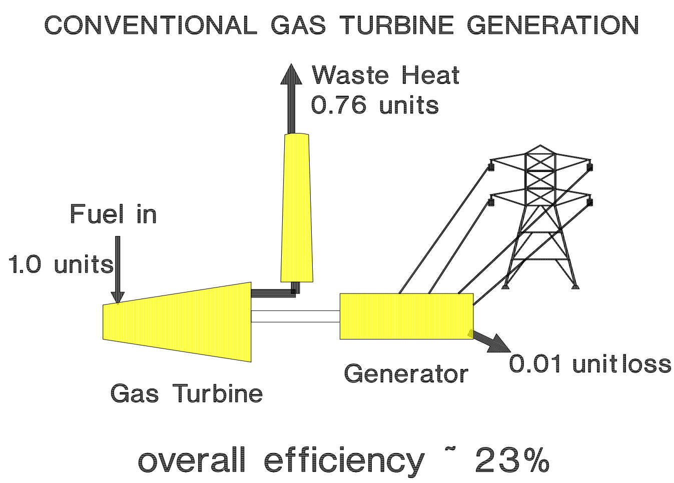

Fig. 10.6 Open Circuit Gas Turbine

A typical OPEN CIRCUIT gas turbine station, which was the only form of gas turbine in use until mid 1990s, is shown in Fig. 10.6 .

The turbine is nothing more than an enlarged aircraft engine. Gas is burnt and the gases expand through the turbine to provide motive power for electricity generation, but the temperature of the waste gases is very high so the overall efficiency is low. These stations were used at peak times only as they could be 'fired-up' in about 3 minutes.

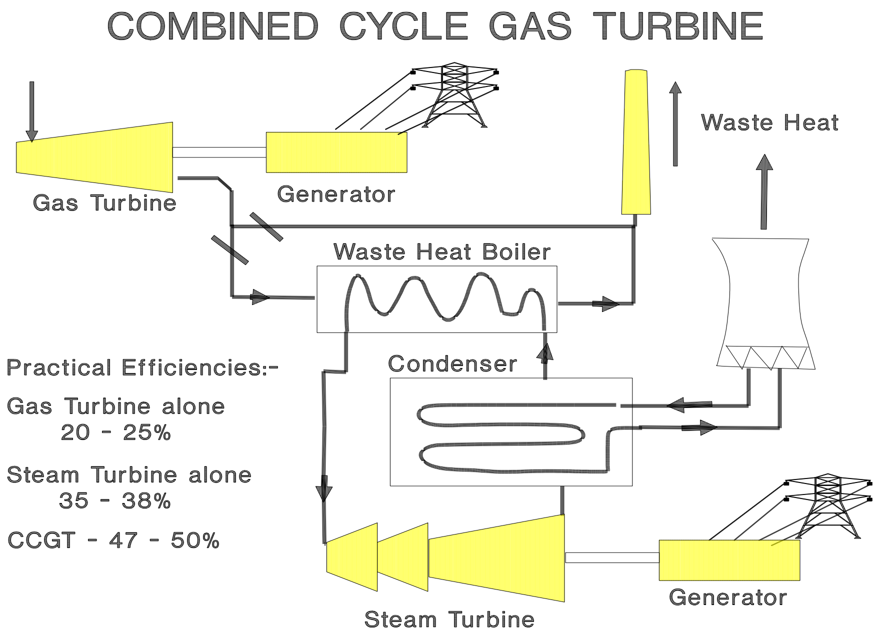

Fig. 10.7 A typical configuration for a CCGT

Combined cycle gas turbines (Fig. 10.7) generate electricity at two points - firstly from the gas turbine, and secondly from the steam turbine. The majority of the exhaust heat from the gas turbine can be used to raise steam, but in most cases there will still be a condenser to reject low-grade waster heat.

The first CCGTs had an efficiency of 47%, significantly above that of the coal fired power station. Newer CCGTs now achieve over 50% with claims of stations with overall efficiencies as high as 56%.

The CCGT station we shall be visiting on the field course has an efficiency of about 56% and is has the highest efficiency of any station in the UK.

NBS-M016 Contemporary Issues in Climate Change and Energy 2010

Practical/Discussion Period - 10th February when you are not having a briefing session

The following are some questions/statements which it is hoped will promote discussion in small groups. The questions and statements are all related to Energy or related matters, and the intention behind this is to promote awareness and to assess what is known already by students taking the course. Some of the questions are relatively easy and require just a few words to answer. Others need some thought.

Spend about 40 minutes discussing the questions in your group. After about 45 minutes, the whole class will discuss the answers.

Answers to these questions will be posted on the WEB after the session.

---

1. When cooking vegetables on a stove. How much energy (as a percentage) is saved by putting a lid on the saucepan.?

2. What are the major sources of heat loss from a house? List the conservation measures which should be adopted in order of effectiveness, and also cost? What measures would you take to improve the energy efficiency of your home?

3. How important is insulation to the fabric of a building in a warm climate compared to that in a cold climate?

3. By time switching the heating in a house so that it is off from 11pm until 7am the next morning, a saving of one third in energy will be possible. Is this correct? What disadvantages are there from time switching ?

4.
Either

a) It is often argued that with a well insulated hot water tank it does not matter if the heating source is left on. In what circumstances is this statement correct, and in what circumstances is it not?

Or

b) A well insulated house will save proportionally less energy than a poorly insulated one when the heating is time switched. Is this statement correct?

5. What problems does the Electricity Supply Industry in the UK have in meeting the targets set for CO_2 and SO_2 emissions? Does it make sense to fit Flue Gas Desulphurisation plant onto our coal or oil fired plant?

6. Fluorescent lights use as much energy when switched on as they do in running for 15 minutes [some people say 30 minutes] or is this a myth?. What evidence can you use to confirm this or otherwise..

7. If we effective in promoting Energy Conservation in the UK then we will obviate the need for between 2 and 5 large power stations. Is this necessarily correct? Under what circumstances would it not be?

8.
Either

a) Aiding those on Low Income to insulate their homes will provide significant savings in costs to those involved, and will also save substantial amounts of energy for the country as a whole.

Or

b) The Government should target Energy Conservation schemes which are the most effective in reducing the demand for Energy.

9. You return home to your house at 16:30 to find the house feeling cold. (you have time-switched the heating to come on at 16:00). Which of the following would you do?:-
   a) turn up the room thermostat;
   b) turn up the boiler thermostat;
   c) reset the time clock;
   d) nothing; set an alarm!

   Explain your answer

10. The radiators in your room is fitted with thermostatic valves. The room is only just OK with regard to temperature, but the radiator feels very cold. What would you do, adjust the valve or leave it as it is?

Space for notes.