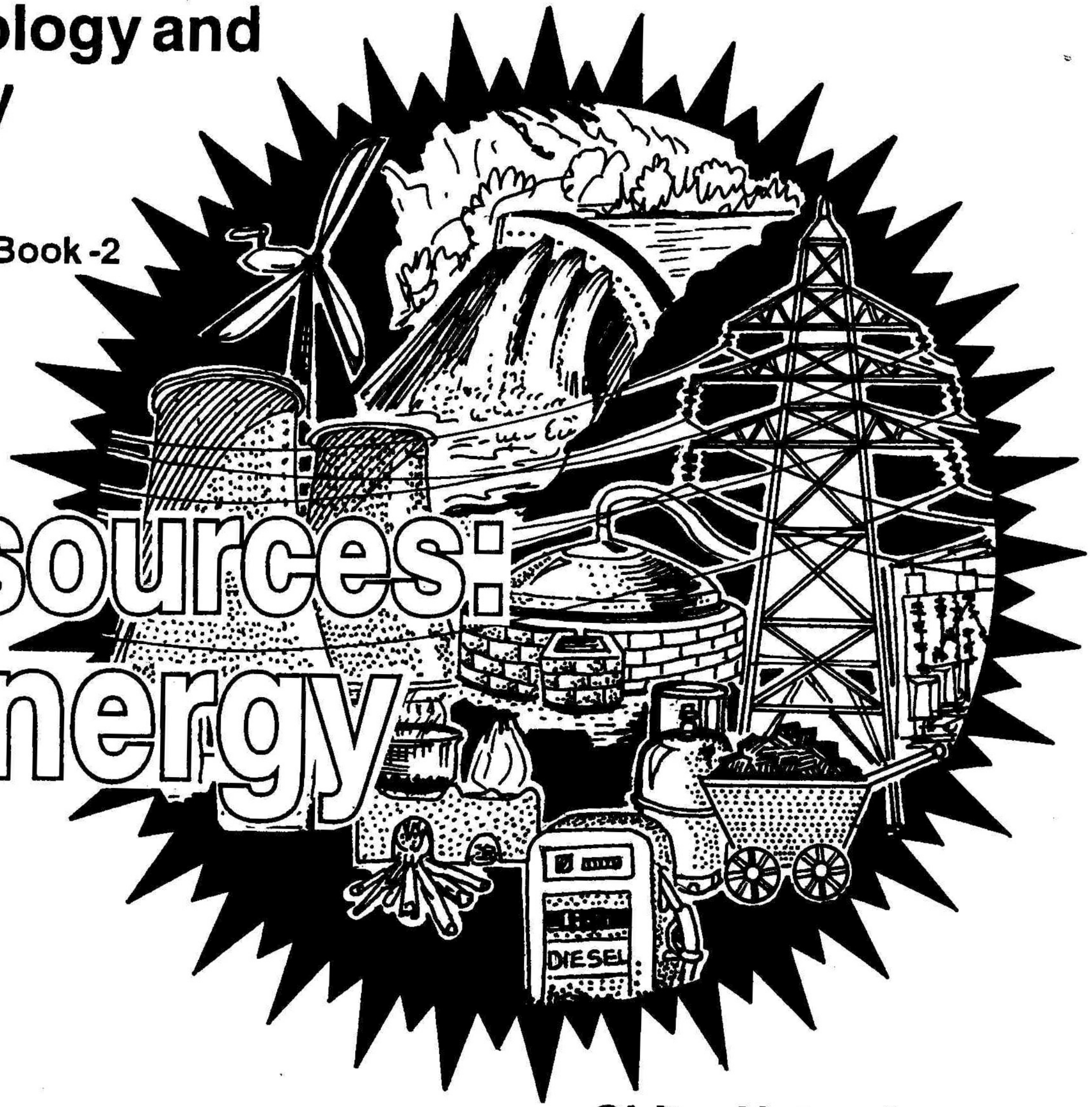
Activity Based Foundation course on Science, Technology and Society

Curriculum Book -2

Resources: Energy



Chitra Natarajan

Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research

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Series editor: Chitra Natarajan
Cover illustration and layout: Anand Ghaisas
Computer graphics: Yogita Parab

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The 'Activity Based Foundation Curriculum' has its genesis in the project for talent nurture among post-school students funded by the J.N. Tata Endowment Trust and conducted by Homi Bhabha Centre for Science Education (HBCSE) for three years since 1993. Besides providing adequate funds for the project intended for developing 'good citizenship qualities' among students of grades 11 and 12, the benevolence of the Late Mr. D.K. Malegamwala allowed the Centre both intellectual and economic freedom to select students and to experiment with innovative content and mode of interaction. After him, the project has received continued support from his successor, Dr. Suma Chitnis, Director of the J. N. Tata Endowment Trust.

The sensitivity to current issues and concern about education of young people evinced by Mr. V.G. Kulkarni, Founder Director of HBCSE, guided the project from its inception. Several issues addressed in the programme had their origin in a book planned by Mr. V.G. Kulkarni, Dr. G.P. Phondke Dr. S. Pandya and the author. Discussions with Dr. Phondke and Mr. Kulkarni have enriched the content of the series. In fact, the idea that 'survival of humankind' is an important basis for discussing the issues, was suggested by Dr. Phondke.

HBCSE Director, Dr. Arvind Kumar's commitment to enrichment of students and his participation and support in drawing up the content and format of the programme, contributed immensely to the success of the project. The series of booklets, of which this is the second one, is a direct outcome of the programme. Dr.Arvind Kumar has been actively involved in planning the overall content of the booklets. His encouragement and gentle nudges have been useful in bringing them out over a reasonable time span.

Besides Dr. Arvind Kumar, Drs. Bakhtaver Mahajan, Sugra Chunawala, G.C. Pal and Ms.Sandhya Karande conducted several sessions. Some of them will be writing a few of the booklets. Besides encouraging the project, Dr. H. C. Pradhan, through the programmes he has coordinated, has provided me opportunities to test some of the activities included in this booklet on talented students of secondary and higher secondary.

The participants of the programme in Mumbai were students from arts, commerce and science faculties of two junior colleges in the vicinity of the Centre. They performed many of the activities included in the books and thus enriched this endeavour by their enthusiasm and feedback. Their quest for meaningful activities is the *raison d'etre* for this activity based curriculum.

Bringing out books of this kind involves a variety of tasks, like clarifying references, getting drafts printed, choosing appropriate illustrations, coverpage layout, photocopying, and so on. As in the first book, in referencing, wordprocessing, printing and illustrations, it is a pleasure to acknowledge Ms.Yogita Parab's help, which was often sought and willingly given. Drs. G. Nagarjuna and K. Subramaniam have been of immense help in providing the needed human interface in all our computer interactions. Everyone at the Centre contributed to providing a problem-free working atmosphere.

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Chapter 1

The foundation curriculum

1.1 The need

The complex web of interactions between all spheres of human activity demand that prospective decision makers possess a repertoire of skills complemented by a reasonable capability to communicate their strengths, in oral and written form. Many of these skills are dependent on the domains of specialization: the study of biology may hone observational skills and the ability to classify and categorise; mathematics calls for logical skills, and the pursuit of sociological sciences calls for critical thinking and the ability to make complex linkages.

Both teachers and the taught readily acknowledge that science, technology and society are intimately linked. However, these linkages are complex. Hence, they require different methods to be adopted in classrooms to encourage the students to form such links. These pose problems for the teacher.

A factor that makes teaching issues at the interface of science, technology and society even more difficult is the proliferation of information. The information boom also comes in the wake of crumbling national barriers for trade and information exchange and a global notion of neighbourhoods. Societies and individuals are reacting more rapidly to global changes than they ever did before. Changing environmental perspectives in Europe have led to migration of polluting industries into the developing countries. Tension in the Middle East or West Asia becomes an immediate cause for concern in Kerala. War, destruction, concern, recovery, rebuilding, and war again - cycles that used to take hundreds of years in previous centuries, now have a periodicity of less than ten years. Contemporary issues not only affect all citizens to some extent, but also call for a systems approach to its understanding and resolution, considering among other things, the technological, economic and socio-cultural linkages. This approach requires a certain attitude to problem solving.

Appropriate training can enable students to acquire problem solving abilities. However, increasing content specialization after grade ten, and lack of an integrated approach to learning before that, are hurdles to such a training. This situation can be partially remedied through intervention programmes, be they at the level of higher education, or during professional on-the-job training.

1.2 A programme for post-school students

Such a training formed the principal objective of the programme funded by the J.N.Tata Endowment Trust, and implemented by HBCSE over three years at Mumbai and also for two years at Solapur. Developing a sensitivity to, and an understanding of, the complex linkages between science, technology and society, was the basis for the programme that aimed at promoting 'good citizenship' qualities among post-school students. The other vital input was strengthening the comprehension and communication skills of the students.

1.3 The curriculum

1.3.1 Genesis

The success of the programme, measured in qualitative terms — heightened sensitivity of the participating students, and their sustained interest has inspired this Foundation Curriculum. The curriculum has been embodied in a series of books. The objectives of the curriculum preclude it from being a textbook. Instead, this curriculum outlines a series of activities that lead the participant from simple issues and ideas to complex ones, requiring the students to make linkages. The activities are also designed to develop the skills necessary for a practical understanding of issues at the interface of science, technology and society.

Most activities suggested in the books have been tried with post-school students during the programme. These could be used by any interested person — a teacher or leader of a forum — to develop comprehension and communication skills among members of a group of young people. They will be working on a broad canvas of issues at the interface of science, technology and society. Outlined below are the objectives of the curriculum, guidelines for interaction, and the topics, chosen for convenience, under which various issues will be discussed.

1.3.2 Objectives

The objectives of the curriculum can be summarised as follows.

- Offer guidance to students in improving their English comprehension, communication and analytical skills, besides quantitative reasoning. English has been chosen in the light of its being the language of global information flow.
- Integrate their curricular knowledge with environmental and developmental issues of concern, thus giving a broad exposure to several disciplines.

1.3.3 Guidelines

Setting guidelines for interaction between the group of students and the teacher, will go a long way in achieving the objectives stated above. A possible set of guidelines could be the following.

a. Sessions should be conducted in a participatory and interactive mode.

b. Sessions should involve thinking across disciplines, stretching the ability of participants to think beyond the obvious connections.

c. Relevance of the issues to daily life should be stressed and participants should be guided in making decisions.

d. Weaknesses and lacunae should be assessed at intervals, through appropriate questionnaires.

e. Skills should be developed through suitably designed activities. These could include the following.

   - writing persuasive essays, poems, letters to local newspapers
   - writing and staging streetplays
   - debates,
   - analysis of tabulated information,
   - comparison and quantification,
   - drawing charts and graphs,
   - designing games,
   - conducting interviews and surveys, and
   - visits to industries, research institutes.

1.3.4 Content

Activities designed to meet the objectives of skill development are grouped under issues of current concern. As already mentioned in section 1.1, the issues are all interlinked and need to be treated that way. For convenience of presentation, these are discussed under the following topics.

- Survival of Humankind: Curricular Philosophy, and The Population Problem
- Education

- Health — Diseases, Drugs, and New Challenges
- Resources: Land, Air, and Water
- Resources: Food
- Resources: Energy
- The Environment — Balance in Nature
- The Environment — Degradation, Science and Technology
- Information Revolution and the Media
- Social Conflicts, Gender Issues and World Peace

The present chapter, an introduction to the curriculum, is a part of each book, with a variation only in Section 1.4. It would be useful to revisit the discussion on *Survival of humankind* given in the book on "The Population Problem".

1.3.5 Target group

The ten activity books are designed to be adequate in content for a 2-year course in Science, Technology and Society at the Higher Secondary level. All the activities can be dealt with over a span of 200 contact hours. Some of the activities require the participants to collect data by library search or survey outside contact hours. However, many activities, mentioned in Section 1.4 of the respective books are essential for giving students a flavour of the issues. These may be covered over a span of 100 contact hours, about 10 hours per book. The large number of activities given in each book allow ample scope for a flexible and innovative approach to teaching the above listed topics.

The activities outlined in the books can, however, be used with any group of individuals with a minimum schooling of standard X (grade 10). It has been found to be harder to work with groups exceeding 30 members. However, this problem can be overcome by dividing the group into subgroups of smaller size. There must be a common language of communication within the group.

Since it is most likely that the books will be used in a classroom situation (say, higher secondary class), the participants are referred to as *students* in all the books.

1.3.6 The group leader

The objectives will be patently met if the group consists of a leader or coordinator, who has more than a cursory interest in the developmental issues of concern today, and enjoys making linkages. The students should be guided not only in making the obvious links, but also to go beyond them.

A coordinator with a formal training in cross-disciplinary thinking has a clear advantage, but a person with an open mind to the ideas of others, and one who feels that students cannot be all wrong, would do just fine. It would be useful for the group leader to be proficient in English, so as to be able to read and comprehend the proliferating information and communicate this to the group. It is most likely that the leader will be the teacher, and hence *teacher* in the books will mean the leader or coordinator of the group.

The leader plays a special role in all the activities outlined. The cardinal principles that govern the interaction of the leader with the group include the following.

i. Understand and value individual and group perceptions.

ii. Encourage listening by setting an example.

iii. While moderating discussions, support the apparently indefensible viewpoint.

iv. Attempt to raise the discussion from the level of free-standing personal statements —'I feel', 'I think', etc., with no accompanying justification — to coherent and logical arguments, with quantification wherever possible.

v. Allow for changing and evolving views during discussions and show a willingness to learn from the students.

vi. Encourage following firm rules during a debate.

vii. Facilitate and liven up discussions by introducing a new angle whenever possible.

viii. Use the 'let us find out' mode as often as is appropriate.

The role of the leader is far from a passive one. Encouraging the diffident student, guiding the overly confident one, finding loop holes in the arguments of a member without lowering self-esteem and being in control of the situation in a class full of thinking individuals is a challenging task. Yet, if viewed as an opportunity to improve one's skills of critical thinking, at the same time creating a generation of thinking individuals, the joy of such interactions can be infectious.

1.3.7 What this is, and what it is not

As already explained in Section 1.3, these books are not substitutes for textbooks, nor are they comprehensive. They are meant to give students a feel for 'real world' problems, without introducing the intractable complexities all at once.

There are very few problems of concern today that have either globally applicable, or locally unique, answers. As in any reasonable developmental approach, the answers to many questions must be sought within a local framework of society, politics and economics. In fact, increasing students' sensitivity to local needs and problems and putting these in the context of global concerns, constraints and opportunities, with examples of solutions arrived at in different contexts, is a tacit aim of the Foundation Curriculum.

Hence, it is an advantage for leaders and group members to have access to information, both local and global. The bibliography is indicative rather than exhaustive. Definitions and concepts can be sought and found in any relevant textbook available in a junior or senior college. Newspapers and locally available magazines could be additional and sometimes valuable sources of issues of debates. Many newsgroups and voluntary agencies provide information and backdated clippigs files free of cost or at a nominal charge. The group must, in the course of the interaction, generate and catalogue clippings files on issues of concern to the group.

The important, but rather difficult, questions of evaluation have not been addressed here. In this curriculum, more than in any other, evaluation of any form is a measure not only of participant's comprehension, but also of the effectiveness of the leader. Test questionnaires have been provided in most of the books as guidelines to assess effectiveness of interaction in the course and to help take corrective measures.

1.4 This book

Second in a series of about 10 booklets planned on issues in *Science, Technology and Society*, this book is the first one dealing with resources. If one is a romantic, one might say that love makes the world go around. And a pragmatist might see money as the mover. Yet, every reasonable person recognises that energy sustains life and causes change.

The basic cooking and heating requirements of rural life are met by wood and dung. On the other hand an immensely varied fuel mix provides the industrialized nations with their highly complex production and distribution systems. No matter what the scenario, civilization is impossible without an adequate energy supply. The energy issue is further complicated by the competition between the use of fossil fuels as an energy source, and their vital role as raw materials for the petrochemical industries, which produce plastics, fertilizers, animal feedstocks, pharmaceuticals, and industrial gases. Thus this issue has implications for the whole structure of modern society.

It is in this context that the activities in this book should be carried out. The energy issue is technical in nature. There has been an effort to reduce the technical content to the bare minimum needed to understand the linkages. A completion of all the activities will take a minimum of 20 contact hours. The effectiveness will also depend on the information that the participants are equipped with. However, Sections 2.2, 2.3, 3.2, 3.3, 3.4, 4.1 to 4.4, 4.9, 5.1, 5.2, 5.5, and Chapter 7 may serve to give an overview of the local and global energy scenarios and possible future options.

Chapter 2

What is energy?

Energy is the capacity to do work or transfer heat. For physicists *work* is different from *energetic activity*. Work is done on an object when an object — be it a mountain or a mole hill — is moved over some distance. Merely holding a weight may tire you. But it is not *work*; lifting a weight is work. Climbing a mountain or a flight of stairs, stretching a spring, and compressing the gas in a cylinder are all work. Does an object lying on the ground have energy? If it is lying on a hillside, you could nudge it, and it would tumble down, doing work by hitting other objects along its way, and forcing them into motion. Hence, the rock must have had energy, the *potential to do work*.

Heat is a form of energy too. Burning lump of coal can produce energy to warm the room. This is a form of heat transfer. Ice melts when heated and sugar is charred on heating. These changes came about by heat energy. Does an apple have energy? Eating it helps you run around, carry loads, and maintains your body temperature at 37.1 degrees Celsius, which may be higher or lower than room temperature depending on where you live and the season.

2.1 Laws of nature

Energy, as we noted above, can be converted from one form to another — the energy of an apple to energy of your motion, fuel energy to a running train. What happens to energy when it is converted from one form to another is governed through certain laws of nature. These laws can never be broken, and they set limits to how far our technological solutions can help us in addressing our resource or environmental problems.

2.1.1 The conservation law

Repeated experimentation has shown that energy is **always conserved**. The **Law of Conservation of Energy** is also known as the **First Law of Thermodynamics**. It can also be stated as: **Energy cannot be created or destroyed**. That means you cannot get something for nothing in terms of energy quantity. Think about this, and answer the following questions to understand the implications of this universal law.

1. You find it difficult to lift a 20 Kg weight. Yet, with the help of levers like crow bars and pulleys you can lift hundreds of kilograms. Does this mean that using levers reduces the amount of work required to lift an object? What happens to the work when you use levers and pulleys?

2. In early times, engineers believed that machines were *work savers*. From this they deduced that if we were clever enough, we could build a machine that would do all the work for free. They called this imaginary device a **perpetual motion machine**. Many clever people tried and failed. Argue that such a machine would violate the law of conservation of energy.

3. When a bus uses up diesel, has the energy stored in the molecules of the compound, diesel, been destroyed? When the fuel is over, the bus will not run. Apply the First Law of Thermodynamics and explain what happens to energy in this situation.

4. If a person must move from her home to her work place, some fuel is needed to provide the energy. Name some ways in which the person can achieve this motion, and also name the fuel used in each case.

The above exercise must have convinced you that there is no magic way to perform work without the supply of energy. And energy does not come free. So, can you get work done without wasting energy? The answer is in another law that governs the conversion of energy to work.

2.1.2 The second law of thermodynamics

Concentrated high temperature heat has the ability to perform work. As the work is performed, some of the energy escapes as low temperature heat, which has little ability to perform work. This is wasted. Whenever energy is converted from one form to another, it is thus *degraded*. This problem cannot be overcome. This is a fundamental law of nature, the **Second Law of Thermodynamics**. According to this law, **whenever energy is transformed from heat to work, some energy must always be wasted.** It is seen in a number of every day events. Do the activities below and realise the implications of this law.

1. When you enter the kitchen to help out, put a plate at room temperature on a pot containing hot food. Observe what happens to the plate. Does the plate ever get cooler when placed on a warm pot?

2. Add a drop of ink to a glass of water. What happens? If you wait long enough, will the ink get concentrated in one section of the water?

3. Imagine your living or study room. Write a paragraph describing a *disorderly* room, and another paragraph describing the same room in *order*. Suppose you have kept the room in order. What is most likely to happen as days pass? Will the room get more ordered? What seems to happen *naturally*?

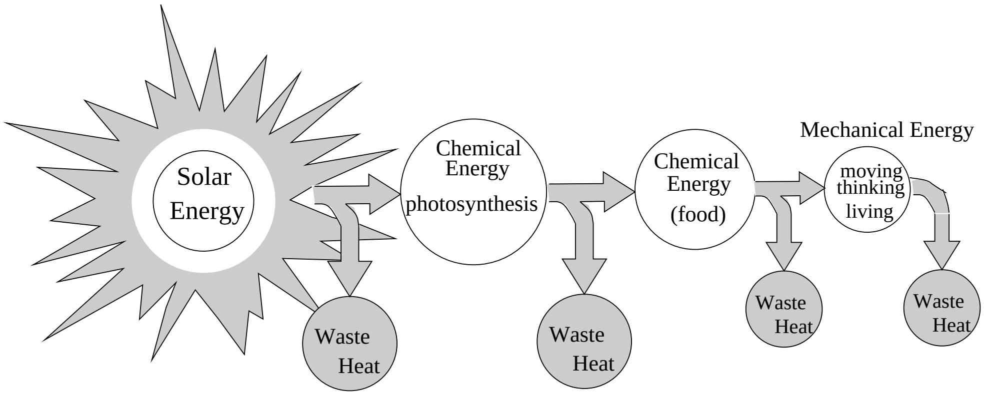
4. Compare the above example to the ink and water system.

5. Plants make the highly ordered complex molecules of sugar and carbohydrates from simple randomly strewn molecules of water and carbon dioxide. What is needed to bring about this order? Show that they do not violate the second law.

6. Study the picture given in Figure 2.1 of energy conversion from high quality solar energy to the low quality heat of air molecules [22]. Apply the second law of thermodynamics to explain the energy conversion in the picture.

7. Disorder of a system is measured by a thermodynamic quantity called **entropy**. It has been observed that **the entropy of an isolated system always increases during any spontaneous process**. Apply

Figure 2.1: The second law of thermodynamics in action.



this statement to the examples above. List more situations that show this statement to be true.

8. Consider two types agricultural systems. In a *natural* field, grains, weeds and scrub bushes all grow together. The plants are consumed by insects, rodents, birds and other animals. A dynamic equilibrium is established after a long time, with many interdependent species existing together.

   In a modern agricultural system, the farmer separates the weeds and cultivates only the grain. Similarly the cattle are separated from rodents and insects. The pests are removed. This system produces more food for human consumption than a natural untended field.

   Which system is more ordered? Which one is more likely to break down if not tended? Which system continually needs a lot of energy to maintain? Go for a hike to an agricultural area in your neighbourhood and talk to a farmer about what he does to maintain his fields.

9. Based on the above examples, write a paragraph connecting technical responses to human problems: the creation of ordered systems and the energy needed to maintain them.

All forms of life are tiny pockets of order, or *low entropy*, maintained by creating a sea of disorder, or *high entropy* in their environment. You have seen the 3 important practical consequences to the second law.

1. The energy in a fuel can never be completely converted to work.
2. Useful high quality energy cannot be recycled totally to perform useful work.
3. Highly ordered systems are more difficult to maintain than less ordered ones.

An important fact about energy is associated with the famous scientist Albert Einstein. According to his theory **energy has mass**. Energy E can be calculated using the familiar relation below, with the symbols m for mass and c for velocity of light.

$$Energy \;=\; mc^2$$

This means that energy and mass are convertible into one another. Considering that the velocity of light is a large quantity, $= 3 \times 10^8$ metres per second, a small mass can in principle release a large amount of energy. However, this is not normally practical. The situation is relevant for nuclear reactions. You will learn more about in in Section 3.2.2

Efficiency

In all conversion processes there is always some waste heat that prevents complete conversion to useful work. The second law of thermodynamics expresses efficiency in terms of the maximum and minimum temperatures attained. In a conventional power plant, high temperatures are attained. Hence, an efficiency of conversion of heat into electrical energy of approximately 50 to 60 percent is possible.

2.1.3 Forms of energy

Sun gives us light and heat. Light and heat are two forms of energy. Energy is available to us not only as light and heat, but in various other forms. You will recall the different forms of energy around you through the activities given below.

Figure 2.2: Alphabet square: find the hidden energy.

S	H	E	A	T	B	O	M	F	I	S	L	G
O	C	L	G	T	I	D	A	L	P	E	R	N
U	D	E	H	P	L	O	G	R	U	A	W	U
N	G	C	A	O	I	B	N	W	V	J	L	C
D	E	T	H	T	G	U	E	I	C	O	N	L
Y	O	R	I	E	H	K	T	N	M	A	X	E
B	T	I	Y	N	T	A	I	D	E	L	O	A
A	H	C	E	T	T	O	C	N	B	P	W	R
G	E	A	S	I	U	Q	M	K	E	H	N	O
I	R	L	O	A	P	E	L	A	S	T	I	C
V	M	N	L	L	I	P	T	O	R	Z	I	A
F	A	D	A	C	H	E	M	I	C	A	L	C
V	L	O	R	F	E	H	Y	S	T	A	I	L

1. Name the forms of energy used by humans, especially those other than electricity. In their homes? In offices?

2. Some processes and situations familiar to you are given below. In each case, there is a conversion of energy from one form to another. Name the forms of energy involved in each case.

   (a) Photosynthesis

   (b) Shining of stars, sunlight

   (c) Thermal power plant

   (d) Hydroelectric power station

   (e) Nuclear power plant

   (f) Cooking stoves

   (g) Electromagnet

   (h) Calling bell

(i) Running a car

(j) Running a bus, truck

(k) Working of watches, pendulum clocks

(l) A trigger releasing a bullet

(m) A rock rolling down a hillside

(n) Lightning

(o) Hot springs (geysers)

3. Find out the forms of energy hidden in the alphabet square in Figure 2.2. Were there forms of energy that you had not listed? Compare numbers with other members of your group.

2.2 Measuring energy

You are now familiar with the forms in which energy appears and the laws that govern conversion of energy from one form to another. How will you practically keep an account of quantities of energy used up, or supplied? You need a measure of energy.

Besides, energy costs money. You need to pay for at least some of the energy you use in your everyday life. Write down the units for the following familiar measurements:

1. weights,
2. volumes,
3. length of cloth,
4. distances between cities, and
5. distance between stellar objects.

Length of a plot of land could be measured in metres or yards. There are many units for measuring energy. A list of some commonly used energy units is given in Appendix A. One of the most commonly used units in the present time is *joule*. How much energy is a joule? Approximately a joule of energy is involved in the following every-day situations.

- The energy gained by a paperback book from the gravitational field of the earth when you pick it up off the floor and put it on the table.
- Kinetic energy gained by a dart when you throw it at a dart board.
- About a tenth of the chemical energy in a grain of sugar.
- One hundred thousandth of the heat needed to make a cup of tea.

You also know about the equivalence of mass and energy. According to Einstein's relation between mass and energy, 1 Joule is equivalent to 10^{-17} Kilograms. This means that large energy changes will lead to very small, undetectable changes in mass.

Consider a situation where you have heated a 10 Kg block of iron from 0 degrees Celsius to its boiling point (about 1800 degrees Celsius). The block would have increased in energy content by about 10^6 Joules. But the mass of the iron increased only by an undetectable 10^{-10} Kg. In nuclear reactions, the converse happens. Large, massive nuclei are split into smaller, less massive nuclei, with an apparent loss of a miniscule amount of mass. This mass is converted into vast amounts of energy, which is released in the reaction.

One must understand the conversion of mass into energy and vice versa in terms of two the important laws of thermodynamics discussed in Section 2.1.

- The total energy in the universe, in any form, including mass, remains unchanged.
- The total entropy in the universe, a measure of the disorder, is always increasing.

The following set of activities requires you to read, think, and find out the units of energy and other quantities related to energy.

1. The *calorie* is a unit of energy, generally used to talk about heat energy. Name other units of energy measurement that you know.
2. List the situations where energy is used up (consumed) or released (supplied). For each case, write down the different possible ways of measuring energy and the units of such measurements.

Table 2.1: Energy involved in familiar situations, and units.

Situations involving energy release / use	**Common units used**	**Conversion to calorie**
Energy used by a mechanically moved machine		
Electrical energy used per second (power) at home		
Electrical energy produced/second say, in thermal power stations		
Energy released in a chemical reactions (rusting and burning)		
Energy released in nuclear reactions (like in atomic reactors, and in the interior of our sun).		

3. Small lengths like the height of your lunch box or the diameter of your pencil are measured in centimeters and millimeters, while cloth for your dress and distances between towns are measured in meters and kilometers. Each of these units is related to the others by simple factors. For instance, you must multiply 1 metre by a factor of 100 to convert it to centimetres. And multiplication by a factor of 0.001 will convert it to kilometres.

   Table 2.1 consists of three columns. The first column has familiar situations involving energy used or released. In the second column, write down the units used to measure energy in these situations. In the last column of Table 2.1, write down the factor by which you must multiply the unit in the second column to get one calorie unit.

4. Many concepts in everyday life are connected with electricity. Find out and write down the units for measuring current, potential difference and electrical power.

We have units and measures of energy. We also have units and measures of economic activity, namely money. The next section invites you to see the analogies between money and energy.

Table 2.2: Energy bank: analogical money and energy terms.

Money terms	**Energy terms**
Income	
Capital	
Deposits	
Interests	
Savings	
Expenditure	
Withdrawals	

2.3 Energy bank - an analogy

Energy can be compared to money in many ways. In this analogy, Earth is an *Energy Bank*. In the case of money transactions, for large investments capital is used, and for monthly expenditure periodical income is used. It is important to maintain a balance in your account. Payments made by cheques will bounce if there is no balance in your bank account.

Fossil fuels are like capital. Capital once used is gone for ever. Sun, wind and moving water are like income sources. Income is regenerated with effort and intelligence. Table 2.2 gives the terms we use while dealing with money. Fill the second column in the table with corresponding examples of energy terms. When does the similarity between currency and energy break down?

List as many reasons as you can to justify that it is necessary to use a variety of fuels, or energy currency, to satisfy the daily energy requirements. Think of the advantages of using different fuels, and the disadvantages of each fuel in fulfilling all our needs.

Chapter 3

Energy sources

Civilization is impossible without an adequate energy supply. However, in the last few decades, there has been a threat of energy crises. According to the basic laws governing energy that you have discussed in the last chapter, energy cannot be destroyed. It can only be changed from one form to another. Hence, strictly speaking an energy problem should not exist.

On the other hand, **fuel** is an accumulation of matter and is a store of energy. Fuels can be depleted. The energy stored in them is ultimately converted to *low quality* heat, which as you have realised, cannot be reconverted to the original fuel mass. The situation is further complicated by the competition between the use of fossil fuels as an energy source, and their vital role as raw materials for the petrochemical industries. These produce plastics, fertilizers, animal feedstocks, pharmaceuticals, and industrial gases. So the crisis is one of fuel availability.

These arguments require that you take a serious look at fuels — the energy sources — their variety, geographic distribution and abundance. These issues will be discussed in this and the following chapters. In the next chapter you will analyse historical milestones in the developments of energy sources, armed with the hindsight you will have gained in the following activities. The information you digest in this chapter will help you make the right linkages in the activities in Chapter 5 on energy use.

3.1 The primary source

1. List a few sources of energy. Where on earth would you normally find these sources?
2. Which of the sources you have listed can you relate directly to solar energy, with a single conversion step? Are the other sources related in any way to energy from the sun? Draw a flow chart to indicate the energy conversion pathway.
3. For energy that you feel have no origin from the sun, write down the sources and pathways to indicate how these sources were produced.
4. Figure 3.1 indicates what happens to the radiation from the sun reaching the earth [31]. How much of the total solar radiation reaching the earth is retained by the plants?
5. In the picture in Figure 3.1, how would you describe the energy flow in the earth system? Choose one of the options below and attempt to justify your stand.
   (a) Energy flow on earth is like a cycle with input and outputs. Draw a cyclic flow diagram showing the conversion of energy within the earth system, writing each energy conversion system in a square box. Name the inputs and outputs.
   (b) Energy flow in the earth system is a *one-way street*, that is, all the energy that flows into the earth also flows out of it. Draw a linear flow diagram showing the recycling of energy within the earth system, writing each energy conversion system in a square box. Name the inputs and outputs.
6. Use the information in the figure to write a paragraph on solar radiation and the earth's climate.

Energy from the sun sustains life on earth. Fuels are primarily formed by the energy input from the sun. You do not have to pay in currency for basking in the sun, or even cooking your meal in it. Rural people use dung cakes from their cattle, or twigs from their environment, to cook their food without having to pay for it. However, electricity is measured in economic

Figure 3.1: Solar radiation and the earth.

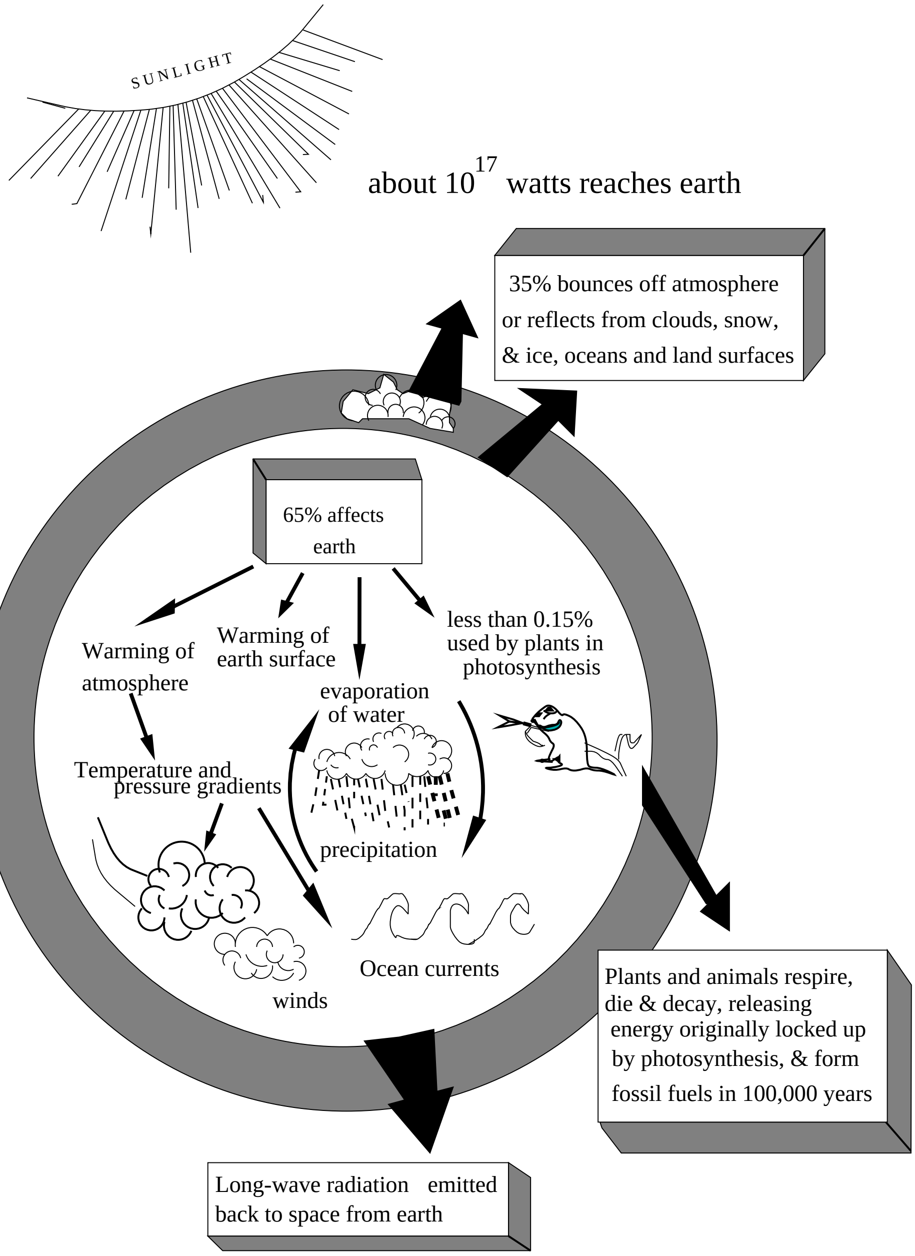
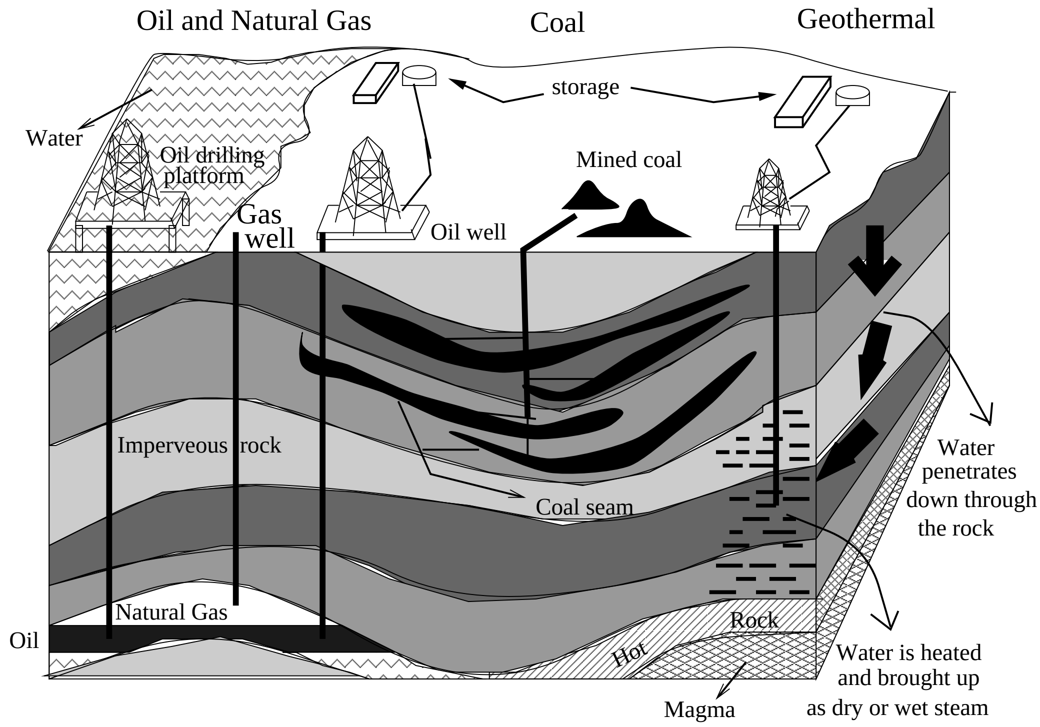


Figure 3.2: Fuels from the earth.



terms. You also pay for the petrol and diesel that runs the taxis and buses you use. Commercial energy is largely produced from fuels that take a long time — even millions of years — to regenerate. Hence these fuels are called non-renewable energy sources.

3.2 Non-renewable fuels

Most commercial electrical energy today is produced by generators driven by steam from the burning of fossil fuels like coal, oil, natural gas, or from nuclear sources or by hydropower. You will discuss the nature of these fuels in this section. Figure 3.2 gives a picture of how and where on earth you will find the various energy resources in the earth's crust.

3.2.1 Fossil fuels: coal, oil, natural gas

Fossil fuels are derived from the remains of organic matter, like trees and dead organisms deposited long ago. Depending on the organisms, and geological and climatic conditions of the location of deposit, they may result in coal, oil, or natural gas. How this happens is briefly described upon below.

Coal

Coal is a solid formed in several stages as plant remains are subjected to intense heat and pressure over many millions of years. It is a complex mixture of organic compounds; over three fourth of its weight is carbon. It may contain varying amounts of water, and small amounts of nitrogen and sulfur. Lignite and anthracite are low-sulfur hard coals. Bituminous coal is a high-sulfur hard coal. Peat is an early stage during coal formation. While anthracite has the maximum energy content with minimum sulfur content, peat has a low energy content. Coal is used to generate electricity, converted to coke for steel industry or burned to produce steam in manufacturing processes.

1. Coal is one of the most abundant fossil fuels in the world. Where in India would you find coal deposits? Mark the points on a map of India given in Appendix D.

2. What is the kind of coal — its sulfur content and heat content — available in different parts of India?

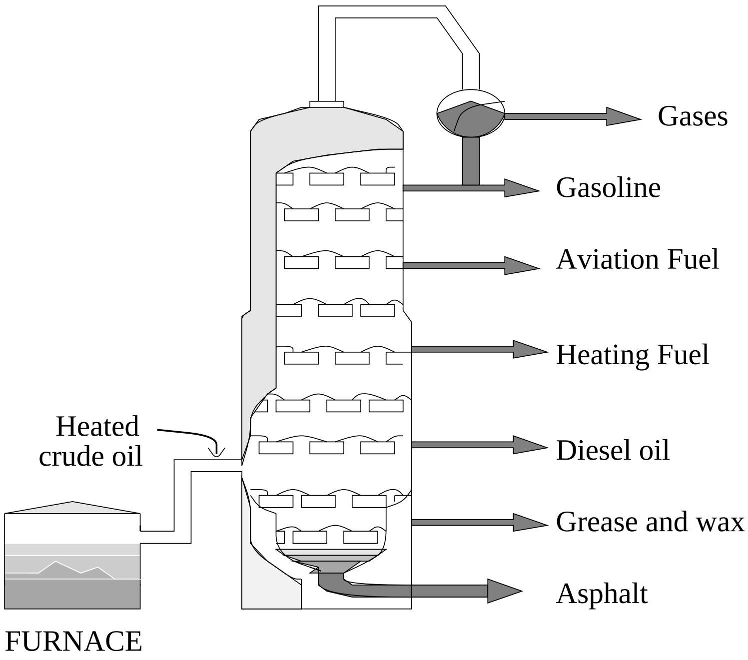
3. Coal has to be mined, transported to power stations for electricity generation which in turn is distributed to homes, industries and offices. At each stage, discuss the problems that can arise, in terms of loss of energy, environmental damage, and risk to life. How would you solve these problems?

Oil

Oil may occur in the form of crude oil, oil shale, or tar sand.

Crude oil is a sticky liquid consisting mostly of hydrocarbon compounds with small amounts of oxygen, sulfur, and nitrogen compounds. Crude

Figure 3.3: Fuels derived from oil for a variety of uses.



oil and natural gas are often trapped together deep within the Earth's crust as shown in Figure 3.2. Most crude oil travels to a refinery. There it is heated and distilled to separate it into various components. This is depicted in Figure 3.3.

Oil shale is fine grained rock that contains a solid, waxy mixture of hydrocarbon compounds called **kerogen**. The shale oil is refined before use. It yields less net useful energy than crude oil.

Tar sand is a mixture of clay, sand, water, and a sticky black, high-sulfur heavy oil (bitumen). These are yet uneconomical for energy.

Natural gas

In its underground gaseous state, **natural gas** is a mixture of $50--90\%$ by volume of methane, and smaller amounts of heavier gaseous hydrocarbons, such as, propane and butane. When a natural gas field is tapped, propane and butane are liquefied and removed as **liquefied natural gas (LNG)**. This highly inflammable liquid is then transported to its destination in refrigerated tankers.

1. Study Figure 3.3 and list the uses of fuels derived from oil.
2. Now that you know the purposes for oil-derived fuels are needed, write a paragraph on the future needs of oil in India, its increases and the chances of these demands being met.
3. India imports oil even now. How will our future oil demand affect our foreign exchange reserves?
4. Do you think we can reduce the demand for oil-derived fuels without affecting the country's productivity?
5. How can we offset the foreign exchange spent on import of oil and natural gas through increase in productivity? Write a paragraph on the possible ways that you come up with. Compare your individual answers with others in the group. Write up a policy draft using the suggestions of the whole group.

Besides coal, oil and natural gas, there is one more energy source that we derive from the earth in the form of a mineral. You guessed right if you thought of fuels for nuclear energy production.

3.2.2 Nuclear energy

Nuclear energy refers to the energy consumed or produced in modifying the composition of the atomic nucleus. The energy released in nuclear reactions is a factor of 25 million greater than in the combustion reaction of a gas like methane. Nuclear power plants harness the enormous energy released from nuclear reactions for large-scale energy production. In modern coal plant the combustion of one pound of coal produces about 1 kilowatt hour (kW-h) of electric energy. The fissioning of one pound of uranium in a modern nuclear power plant produces about 3 million kW-h of electric energy. It is this incredible energy per unit mass that makes nuclear energy sources of such interest. It is percieved by many as a source of inexpensive, *clean*

Table 3.1: Details of nuclear power projects in India in 1995.

Project	**District, State**	**Total capacity in megawatts**
Under operation		
Tarapur (unit 1,2)	Thane, Maharashtra	320
Rajasthan (unit 1)	Kota, Rajasthan	100
Rajasthan (unit 2)	Kota, Rajasthan	200
Madras (unit 1,2)	Chengalpettu, Tamil Nadu	440
Narora (unit 1,2)	Bulandshahr, Uttar Pradesh	440
Kakrapar	Gujarat	440
Under Construction		
Kakrapar (unit 2)	Gujarat	Not known
kaiga (unit 1, 2)	Uttar Kannada, Karnataka	440
Rajasthan (unit 3,4)	Kota, Rajasthan	440
Future Projects		
Kaiga (unit 3-6)	Uttar Kannada, Karnataka	880
Tarapur (unit 3,4)	Thane, Maharashtra	1000
Rajasthan (unit 5,6)	Kota, Rajasthan	1000
Kundankulam (unit 1,2)	Tirunelveli, Tamil Nadu	2000

power. However, because of the hazardous radiation emitted in producing that power, and calamities caused by accidents, others feel that it may not be a viable energy alternative to the use of fossil fuels or solar energy.

Indian nuclear energy programme

India's nuclear programme was initiated by Dr.Homi Bhabha several decades ago. But our dependence on nuclear power has so far been little. Some countries depend more heavily on nuclear energy than others. France for example, generates about 70% of its electricity from nuclear power plants. Table 3.1 gives the details of nuclear power projects in India as on March 31, 1995 [34].

1. Mark the places on a map of India (given in Appendix D) where nuclear power plants are operational, under construction, or planned in the

future. Use three different symbols to depict the three categories.

2. Is there a pattern in the location of these power plants? What are the reasons for choice of their location? Look up the population of the places, and get information about the industrial output of the states. Are demand for electricity and location of nuclear power plants correlated? Justify your answer.

3. Uranium is the fuel used in many nuclear plants. Where in India is this fuel available? Considering our uranium ores are of a lower quality than other countries', can we sustain a nuclear programme based on uranium for a long time?

4. Why do only a few countries follow a vigorous nuclear programme to satisfy their power needs? List your reasons and then have a group discussion.

3.3 Diminishing resources: fossil fuels

Figure 3.4 [17] shows how fossil fuel production has varied in the world as a whole, and in different categories of countries, over the years from 1961 to 1990. The categories are given in Appendix B. Study the trends in the figure and discuss the following questions.

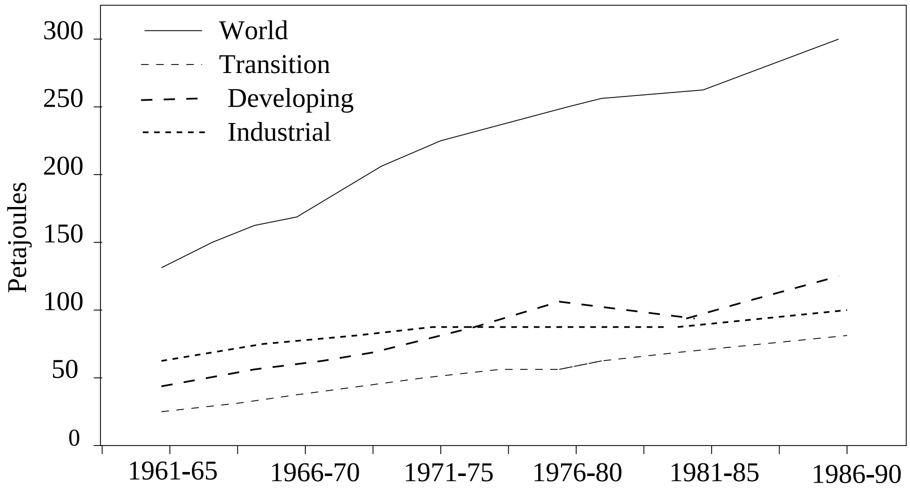
1. The graph shows an increasing fossil fuel production for all categories of countries. Are there differences in the rates of increase for the three categories? During which years?

2. There have been two *oil shocks* during the period depicted in the graph. Estimate when they must have occurred.

3. Which category shows the highest rate of increase after 1980? Does this necessarily mean that these countries were developing at a faster pace? What else could have happened?

Figure 3.5 shows the variation of world oil production over 200 years, from 1900 to 2100 [2]. The solid line till 1974 shows actual values, while the remaining part of the curve is calculated on the basis of known reserves, technologies

Figure 3.4: Five year averages of fossil fuel production, 1961-90.



and expected demands. The units used for measuring the quantity of oil is Quads, short for Quadrillions, corresponding to oil equivalent of 10^{15} British thermal units (Btu) of heat energy.

1. Explain why the curve rises slowly in the initial stages. Over what years is the rise slow? What does this mean in terms of oil use in those years. Give its historical importance.

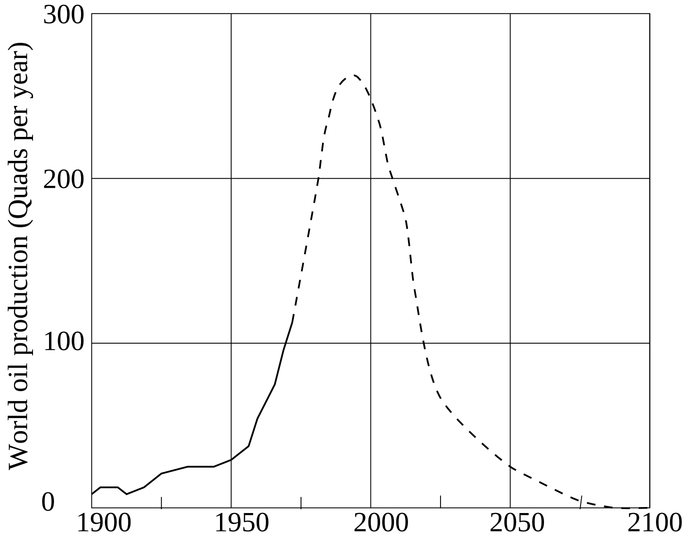
2. What conditions may have caused the rapid increase beyond the 1950's? What role do the following factors play in causing an increase in oil production:

   - countries gaining independence from colonial rule,
   - the industrial policies of newly independent countries, and
   - science and technology developments.

3. According to Figure 3.5, in which year was the production expected to peak? What should have happened after 1995?

4. What factors would you need to know or assume to make a prediction about oil supply in the next decade?Which of your assumptions could go wrong? Why?

Figure 3.5: Oil supply in the world., 1900-2100.



5. What would be the consequences of diminishing oil production? How would people in various countries respond to such a situation? How would a lay person like you come to know that the oil production is diminishing?

Non-renewable energy sources are exhaustible. It is only a question of time before they are depleted. Discovery of new reserves, new scientific knowledge and technological tools may stretch this time somewhat, but not for ever. However, the future is brightened by some perennial sources of energy-renewable energy. You will discuss this in the next chapter.

Chapter 4

Renewable energy sources

You have seen in Section 2.3 that some energy sources can be regenerated in reasonable time scales, with effort and intelligence, in keeping with the laws of energy conversion. Such sources are termed as **renewable energy sources**. Other energy sources, when once used take hundreds of thousand years to regenerate. They are lost for ever for all practical purposes. These are termed as **non-renewable sources**. It is interesting to see the meanings of the words renewable and non-renewable and how they may change with context.

1. You are ready for a bath. You are filling your bucket from the tap. You do not want to wait till the bucket is filled, and start drawing water from the bucket with a mug. What could happen in the following cases? Explain in which of the cases, water, for you, is a renewable resource.
   (a) Water is gushing out of the tap and you are using a small mug.
   (b) Water is trickling from the tap.
   (c) Water is flowing at a steady rate, and you are using a medium sized mug.
2. What does the above example tell about the relation between rate of generation (filling), rate of use and renewability?
3. The people of a country called **Fooland** import and begin to cultivate a new variety of tree, the *Coconut palm* on a specific farm area allocated

to it. The fruits harvested were enough to satisfy their needs through the year. Before they imported this new variety, the only plants they knew were some small herbs that had to be uprooted after fruiting and regenerated each year. The tallest tree they have known was a banana tree. The people of Fooland applied the same rule to the coconut tree and cut it down after reaping its first fruits. Then they replant the seeds in the allocated area and waited for the new trees to fruit. Following their habit of cutting trees after fruiting, can they get coconuts to satisfy their needs each year?

4. What changes in their life style can make the coconut a resource for them year after year?

5. Coconut palms take about 3 to 5 years to fruit after planting the seedling. Suppose they had imported a tree which took only one year to fruit after planting the seed, would their old technique of cutting after fruiting still give them a steady supply of fruits?

6. You have seen that the rate of use (coconuts per year in this case) and rate of regeneration (time to grow) determine the extent of renewability of a resource. On the basis of what you have learnt from the story of *Fooland* write a paragraph on what makes a resource renewable. Give suitable examples. Compare all the examples given by the group.

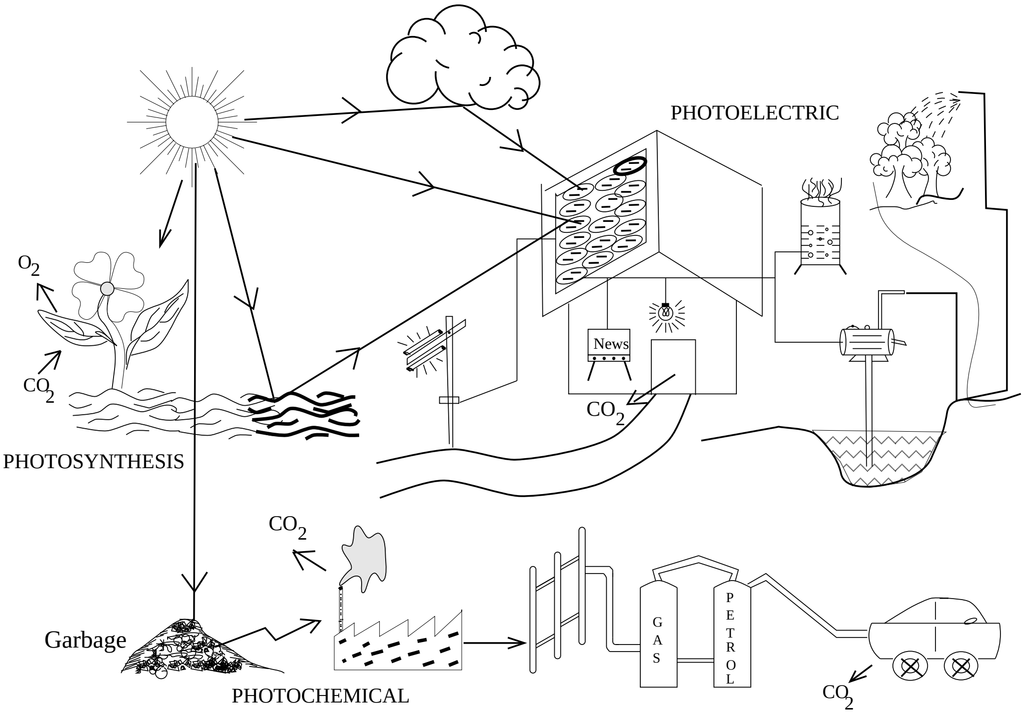
7. List some of the renewable resources you know. Write an instance for each indicating how they may become non-renewable.

A highly populated country like India cannot hope to fulfill her energy needs for all times to come with her own resources of fossil fuels alone. The reserves are limited in quantity, and the cost of production is increasing. We are lucky to be endowed with renewable sources of energy like the sun, wind, waves, tides and biomass. These sources would are replenish in our life times, if used wisely. These could meet a significant part of local energy needs of Indians. You will now discuss our total *energy income* potential from various sources.

4.1 Solar energy

The sun is 400,000 times brighter than the moon, and radiates energy at the rate of 10^{26} watts into space. Less than one billionth of that energy actually

Figure 4.1: Solar energy conversion.



reaches earth, a third of which is promptly reflected back into space [13]. Most parts of India receive sunshine for over 250 to 300 days in a year. Solar energy is used by us in many ways. Figure 4.1 shows schematically some of the useful forms of sun's radiation. You will realise through the following activities, the quantitative value of sunshine in terms of energy for us.

1. It is estimated that on an average, one square meter of surface receives about 6 kilowatt hours of energy per day over half of India [13]. The rest of the country gets less energy. Given that India has a land area of 3,160,790 square kilometres, what would be the total solar energy received over the sunny half per year? Write it in terms of kilowatt hours per year.

2. Assuming that only 1% of this energy can be utilised, what is the total usable energy? If we tap it at 10% efficiency (for every 100 watt input, we get electricity worth only 10 watt) what is the total energy we can get as electricity?

3. The present electricity generation in India is about 8000 Petajoules. Use the units given in Appendix A, and find the annual electrical energy in kilowatt hours produced at present in India. This energy is produced using non-renewable sources. Compare this number with the electrical energy we can potentially tap from the sunlight. What do you conclude from this? Write a paragraph explaining your arguments for a solar energy programme in India.

Photo-voltaic systems produce electricity when sunlight falls on the photo-voltaic cell. Read the following report about solar energy use in Kalyanpura village in Gujarat State, [13]. Read the report and discuss the issues raised.

> In Kalyanpura Village, in Gujarat State, a specially designed 4kW solar photovoltaic power pack has been installed to provide electric supply for its street and domestic connections. The power pack provides electric power for 16 street lights, 110 domestic lights and a community colour TV set. It saves 6015 units of electricity every year. Plans are under way to extend the capacity of this power pack by another 4 kW. This will not only result in increased hours of light availability, but the village will also then have 30 fans, and even a flour mill and rural industries such as a diamond cutting machine. This will bring prosperity to the people. If photo-voltaic cells were cheaper to produce, generating electricity for rural needs would be as simple as sun-bathing.

1. How many lights and TV can Kalyanpura village sustain using a 4 kW power pack? Estimate the average wattage of street lights, domestic lights and TV used in the village. How does this compare with the amount of energy used in your locality? Consider a building, or group of buildings in a housing society, or a group of bungalows for your comparison.

2. How much electrical energy does the village consume over a year, if all of it only came from solar energy? How did you estimate this? Assume, as is normal, that the village has about 100 houses with an average of 7 members in each. What is the per capita electricity consumption in the village?

Table 4.1: Biomass sources, location and alternate uses - a survey format.

Biomass fuel type	**Location of abundance**	**All uses, by order of priority**

3. The report talks about bringing prosperity to the people of the village with solar energy. Do you think this is feasible? Justify your answer.

4. **Propose that a sunny village can be made self-sufficient and prosperous using present technology and locally available solar energy.** Organise a structured debate in the group, with the two sides arguing for and against this proposition.

4.2 Energy from biomass

Biomass is any form of organic material obtained from plants and animals from which energy can be derived by burning or biological conversion.It includes wood, cow dung, agricultural crop residues, forestry residues, and scrap paper. Fermentation is one of the bioconversion processes that produces energy from wastes. In developing countries, as you have seen before, almost 50% of the energy needs is met by biomass, while in India, it is about 30%. However, the supply of this vital fuel is often not managed renewably, and the fuel is burnt wastefully. You will discuss this in the following activities.

1. List the various sources of biomass in the first column of Table 4.1. In the second column, describe the places where these would be produced in abundance and of quality suitable for fuel. For instance dung will be available at dairy farms. List the taluka/districts.

2. About 4,500 kg of milled rice produces around 900 kg of husk. By that

count, about 36 million tons of rice husk is produced annually in India. The energy content in wood and husk are same by weight, namely 13 MJ per kilogram. If energy extraction from husks is done at an efficiency of 50%, what is the total energy we can produce annually in our country through rice husks alone? How many megawatts of power would that be?

3. Add to your calculations, the vast amounts of rice straw also generated in rice harvesting, and the energy potential increases even further. In 1990, *a 10 MW rice straw-based pilot 'research and development thermal power project', the first of its kind in the world, was taken up through the Punjab State Electricity Board.* Why have we been so late in tapping this energy resource? List some of the possible reasons. Find out alternate uses of rice husk and straw, such as in cooking. How could the total efficiency of its use be improved?

4. Fuel is one of the uses of rice husk, an agricultural byproduct. In the third column of Table 4.1, list all the alternate uses of the biomass listed in column 1.

5. Argue that it would be unwise to use all available agricultural waste for energy generation. Give as many reasons as you can. List a set of guidelines stating under what conditions it might be prudent to use a particular type of biomass as fuel, and up to what quantities (fraction of that produced,agricultural need, etc.).

6. Another source of biomass is energy plantation. Energy plantations are usually fast growing species on degraded lands. Along with fuel-wood, they also ensure fodder, employment and a better environment to rural people, with long term benefits to soil and the ecosystem. It is reported that [13] if energy plantations are raised in even 10% of the wasteland in Gujarat state, they could provide for local fuel-wood needs and produce biomass sufficient to generate 1500 MW of electricity. Argue that this facility could be misused if there is no provision to ensure the total participation of local people in the project. List all the possible ways in which such a programme could cause harm.

7. Scientists at the Nimbkar Agricultural Research Institute (NARI) at Phaltan, Maharashtra. have produced industrial alcohol from sweet

sorghum straw through fermentation and solar distillation. Sorghum yields gram for flour, its stalks provide the juice for fermenting to alcohol and the bagasse provides fodder for animals. Thus one crop from the same piece of land provides food, fodder and fuel. Write an essay on the advantages of promoting such crops. Also outline the major problems that could arise if this were carried out indiscriminately.

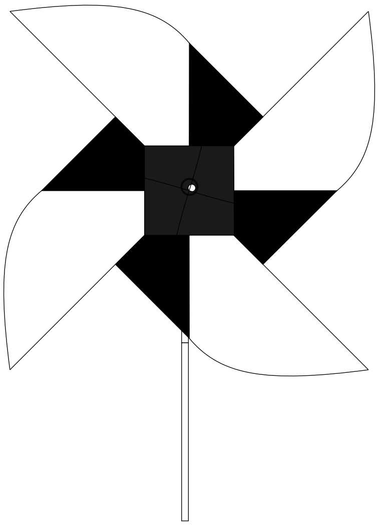
8. Biogas has become practical both in rural and semi-urban areas. Biogas plants provide cooking fuel, nutrient rich fertilizer and electricity. There are individual and community biogas plants. Sulabh toilets are night-soil based biogas plants attached to public toilets. Over 11 lakh biogas plants have been set up in the country so far. They produce a fuel equivalent of over 3.8 million tonnes fuel-wood per year in addition to over 18 million tonnes of manure. We can possibly use alternate sources such as banana stems, eucalyptus leaves, water hyacinth, and kitchen waste to complement cow-dung. Write a persuasive article for the local newspaper asking for this potential energy source to be given greater attention. Explain in what ways your suggestions would be beneficial to the locality or city as the case may be.

9. There are places in our country, like Timarpur in New Delhi and Bantala near Calcutta, where garbage is used in incinerators to generate electricity. The Bantala plant was built at a cost of Rs.10 lakhs and uses 500 kgs. of solid leafy garbage per hour to produce 5 kW of electricity. Write a paragraph giving the benefits and problems of having such waste-to-energy plants.

4.3 Wind energy

Although wind energy has been used for thousands of years, developing the technology to meet the needs of the modern world has been a major challenge. The main difficulty is to produce and install machines that will produce the optimum amount of energy, safely and reliably. Many thousands of stand alone wind turbines are in operation around the world, mainly in remote areas. Let us see why they are gaining ground as a preferred source in some areas, and yet we would be chasing wind mills (like Don Quixote) if we were to advocate it as a major resource.

Figure 4.2: A wind driven toy.



Once upon a time the toy vendor was a common sight in the by-lanes of cities and in towns and rural areas. Now he is less common, though still seen in rural and small town fairs. Locate a toy vendor and find out how many different toys are operated by wind or blowing air.

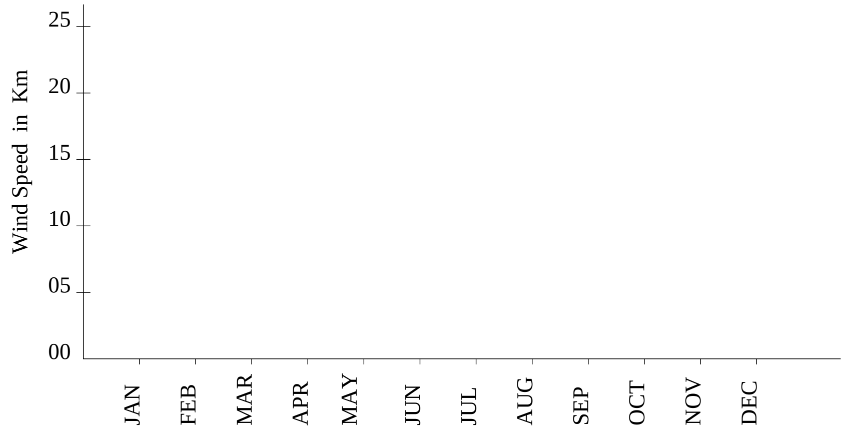
Make as many small wind operated toys as you can, like the toy windmill or even a toy aeroplane. Many such toys are illustrated in a book on Indian Toys [20]. One adaptation is given in Figure 4.2. Use materials like waste paper, broom sticks, etc. One idea would be for you to form groups of three persons, and each group could make many toys. In the end, the whole class could judge who made the most number of toys, the most innovative toy, etc. The condition is that all of them must be wind operated. You could pool your toys and have an exhibition.

1. Write a short note on each of the toys you made summarising how it works. Illustrate your write-up with a simple sketches.

2. Note down the wind speed in your area for a whole month. Find the average for the month. Do this for a whole year. Plot the average wind speed in a month versus months in the year in Figure 4.3.

3. A large number of installations in the form of groups of wind turbines

Figure 4.3: Wind speed in different months over the year in your town.



is called a wind farm. Enumerate the advantages of wind farms over conventional power plants running on fossil fuels. List the problems that may restrict the use of this resource over a wide region, and on a grand scale.

4.4 Hydro power

You have all heard about hydro-electricity and the controversies regarding large dams on some of our country's major rivers. Awareness of environmental degradation, displacement of people, and loss of land and livelihood have all activated protests against large dams from concerned citizens in the tropical countries. Moreover, long and high dams have been suspected to increase seismic (earthquake) activity in the surrounding regions. Mini hydro projects are hence becoming more popular. However, they are limited in capacity and pose other challenges.

1. It was predicted in the last decade that the power generated throughout the world from mini and micro hydel projects would be 36 Gigawatts ($= 10^9$ Watts) in 1991. If the total hydroelectric power generated in the world amounted to 8000 Petajoules ($1PJ = 10^{15}$ Joules) in 1991, what percentage of this power was to be generated by the mini projects?

2. Assume the same ratio of big and mini hydro power plants in India as in the world. In the light of your calculations, would you canvass for more mini hydro projects in the country? List the pros and cons of mini hydro projects.

3. One of the major obstacles to building mini hydro power plants is its expense. The energy from this is often not affordable by the small community it is meant for. A new system called the *induction generator controller* (IGC) has been developed which produces electricity as inexpensively as a full scale hydro power station. India would have to invest some research funds and manpower in adapting this to her needs. Is it appropriate to invest in this technology? Justify your answer.

4.5 Energy from the ocean

The oceans are sources of energy in different forms. Humans derive food from fish and planktons. Besides, there is energy in the form of tides, waves, and temperature gradients in the ocean. Considering India's vast coastline, it is worthwhile exploring the use of this perennial resource.

4.5.1 Tidal energy

Tides are generated through the forces exerted by gravitational pull of the sun and the moon and the rotation of the earth. The relative motion of the sun, the moon and the earth produces different tidal cycles and affects the range of the tides. The nature of the local coastline and sea bed also affects the tidal range.

Extracting energy from tides requires a mean tidal difference greater than 4 metres. Being close to estuaries, or certain types of bays, can bring down the cost of constructing dams needed to get energy. The following activities will help you discuss our country's potential to tap this renewable source of energy.

1. Find the length of India's coastline. Which are the seas or oceans that border India? In which direction would you find them?

2. India is known as a peninsula. What is a peninsula? Can you name any other country that can be described as a peninsula?

3. **Bay** and **Gulf** refer to large inlets of the sea into the land mass. Name the bays and gulfs around India, find out where they are.

4. Gulf of Cambay has a maximum tidal range of 11 metres with an average of 6.77 metres. Gulf of Kutch has maximum tidal range of 8 metres with an average of 5.23 metres. The Ganges Delta in Sundarbans gets a maximum tidal range of 5 metres with an average of 2.97 metres. Locate these places on a map of India. In which states would you find them? Are these locations suitable for tidal power generation? Which location should we explore the possibility first? Why?

5. Other such locations along India's coastline with potential for tidal power generation have not been identified. Why is it difficult to find such locations?

4.5.2 Wave energy

Waves result from the interaction of the wind with the surface of the sea. It is a transfer of energy from the wind to the sea. The amount of energy transferred depends on the wind speed, the distance over which it blows over the water surface and the length of time for it has been blowing. The largest potential for tapping wave energy is located between latitudes 40 and 60 degrees both in the north and south hemispheres. Wave power systems convert the motion of the waves into usable mechanical energy, which in turn can be used to generate electricity. These systems can be floating, can be fixed to the seabed offshore, or constructed at the edge on a suitable shoreline. The following activities will familiarise you with where we are with regard to exploiting wave energy.

1. Locate the latitudes and longitudes between which India's coastline lies. What are India's chances of getting energy from waves? Considering its long shoreline, is it worthwhile for India to explore the possibility of obtaining energy from waves?

2. Refer to a political map of the world, showing latitudes, and list the countries that have a better chance of tapping wave energy. Adding

economical and material resource considerations, which countries do you think would have invested in utilising this resource?

3. UK, Norway and Japan are three countries which are tapping this ocean waves for energy. Does this agree with your guess in the last activity? Were there more countries than these 3 in your list? Why do you think they may not be investing?

4.5.3 Ocean thermal energy conversion

Ocean thermal energy conversion or OTEC uses the temperature difference between warm surface waters of low altitude tropical oceans, say about 26 degrees Celsius, and the cool deep waters at 5 to 10 degrees Celsius lying below a depth of a few hundred metres. This temperature difference is used to run a turbine and a generator.

1. What primary energy produces the temperature difference in the oceans? Write a paragraph explaining this phenomenon. Draw a sketch to illustrate your explanation.

2. In India, activities in this area are coordinated by the OTEC Cell at Indian Institute of Technology, Chennai. Compose and mail a letter to this Cell to enquire about the potential of this energy source to satisfy a part of India's energy needs. Discuss the response in your group.

4.6 Other energy sources

Besides the sources we thought about so far, there are others that cannot be strictly termed as renewable sources. However these resources are available in such large quantities that for practical purposes today, they can be considered as inexhaustible. Two inexhaustible sources of energy are geothermal energy and hydrogen. Solar hydrogen sources are, however renewable.

4.6.1 Geothermal energy

Geothermal energy is the natural heat generated from within the earth. Underneath the earth's relatively thin crust of about 12 kilometres on the average, temperatures range from 1000 to 4000 degrees Celsius, and in some areas the pressure exceeds 1360 atmospheres. Carry out the following exercises to discover the potential of this source for India.

1. Geothermal energy manifests (shows) itself in some natural phenomena. Name some phenomena exhibiting this energy.
2. India has a large land mass and hence must have some potential for tapping this energy. List the places in India where these phenomena are manifest.
3. About 10% of the world's land mass contains accessible geothermal resources. This could provide a lot (several million quads) of energy annually. But this energy must be used locally and is uneconomical when transported over distances. List the ways in which this become an attractive option.

4.6.2 Energy from Hydrogen

Hydrogen is one of the most abundant elements in the universe. It can be produced from water. It may also turn out to be a cleaner fuel because its combustion will not release oxides of carbon into the air. Its use was predicted as far back as 1874 in a science fiction novel. How far have we come? Carry out the following activities and discover.

1. The famous science fiction author Jules Verne predicted in his 1874 book titled *The Mysterious Island* that hydrogen would eventually become the major energy source of the future. When asked what will be burnt when coal and other fuels are exhausted, a character in his book responds as follows;

   > I believe that water will one day be employed as a fuel, that hydrogen and oxygen which constitute it, used singularly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable. Some day the coal rooms of steamers and tenders of locomotives will, instead of coal, be stored with these two condensed gases, which will burn in the furnaces with enormous caloric power.

This statement was based on the situation existing in 1874. What would you say, if someone were to ask you the same question, namely, "what will be used as an energy source when all non-renewable fuels, like coal, oil, natural gas are exhausted?" Answer the question in about a page. Be imaginative and creative. Use all the knowledge of science and energy sources that you have, and give as many details as you can. Make the situation vivid.

2. Alternatively, you may imagine an entirely different kind of life style of future generations on earth.

3. It is said, "In an era of hydrogen fuel use, any country near a body of water or with sufficient sunshine, has the potential to turn it into the equivalent of an oil field." Write an essay on this theme, explaining how it is applicable to India.

4. Can you think of the possible unwanted situations caused by all water bodies becoming a prospective energy source? Write a paragraph on the bad social impact of such a proposal.

It would be instructive to discuss the historical development of energy sources.

4.7 Historical milestones

Have human beings always used energy in the same forms as we see today? Before humans discovered the power of fire and tamed it, they used their muscles, which were built from the raw food they ate. Since those prehistoric times humans have come a long way in harnessing a variety of energy sources to enable a comfortable life. Though properties like electric attraction and repulsion have been pondered about since 600 B.C., electricity was unknown as a source of energy till a couple of centuries ago. In this section you will discover some interesting aspects about the history of energy use by humans.

1. Read about the discovery of steam engine and the story of young James Watt. Write a paragraph on its historical importance. What were two significant uses for coal before World War II?

Table 4.2: Milestones in energy development

Year, approximate	**Invention/ discovery**	**No. of fold**	**Energy content/ form, R or NR**
8000 BC	Agriculture, Domesti– cation of animals	10	
300 BC	Water wheels	100	
1700 - 1950 AD	Coal, Oil, Natural gas Nuclear energy	100,000	
1990-2000 AD	Wind mills	100	

2. How did coal come to be mined in large quantities. Write an essay outlining the story of coal, life around the collieries, industrial revolution, workers' unions, and social revolutions that followed. Discuss the issues raised in the group.

3. Trace the history of energy production and use by humans. Trace the early forms of energy use — in the old stone age, age of agriculture, and so on.

4. How has the rate of energy use varied over time? Draw a graph showing the total energy used by humans, say per person per year, as a function of time from 30,000 BC to 2000 AD. Mark on the graph any significant events or discoveries, like agriculture, growth of towns, industrialization, etc.

5. The milestones in energy use by humans are listed in Table 4.2. Fill the last column in the table with individual source that caused the increase in energy. For instance, in the case of water wheel, it was flowing water that provided the energy.

6. In Table 4.2, which of the milestones involved renewable energy sources **(R)**, and which heralded the use of non-renewable sources **(NR)**? Add this information in the last column.

7. Talk with your grandparents and parents about energy sources they had used in their homes when they were your age. Write a page on the

energy sources for heating and cooling giving the variation in cost of energy over three generations (over 50+ years)

8. Discuss your ideas with the whole group.

9. Some of the energy sources (biomass) are locally available and can be used by employing simple technology. These are also often privately owned. Some others, on the other hand, need to be centrally controlled in terms of energy production and use. Note all the points in favour of these two different situations. Also think of what may be the disadvantages to actual users of energy in both the cases. Organise a debate on the topic: **Commercializing energy eliminates the relationship of user communities with their energy sources**.

4.8 Unequal distribution

You have so far discussed the different fuels, and their energy content. You have also learnt that at least some of them can be converted into other forms, and about the laws that govern such conversions. In this section you will revisit these ideas and discover how these fuels are distributed geographically.

1. What appliance do you use for cooking? What other appliances or sources do other people use for cooking? List them all. Against each source, write your estimate of which economic group those people may belong to — rich, upper middle class, lower middle class, poor or very poor. Why are different sources used by different people?

2. Besides cooking and heating food, which other every day activities require energy? List these activities, and the form and source of the energy used in each.

3. Some sources of energy are listed in Table 4.3. Make up a symbol for each source, and show it in the second column. Create appropriate symbols to represent each source. The third column gives the countries or regions of the world where these sources either abound, or are maximally used, or both. The categories are based on the data for 1990-91 [17]. The following criteria have been used to categorize the countries as users of a resource.

(a) **Coal:** countries having more than 50,000 million metric tons of proved recoverable reserves in 1990, of anthracite, bituminous, sub-bituminous and lignite coals.

(b) **Crude oil:** countries having more than 10,000 million metric tons of proved recoverable reserves in 1990.

(c) **Natural gas:** countries having more than 10,000 billion cubic metres of proved recoverable reserves in 1990.

(d) **Uranium:** countries having more than 100,000 metric tons of uranium recoverable at less than $130 per kilogram in 1990.

(e) **Hydro-electric energy:** countries with an installed capacity more 30,000 megawatts in 1990. All the given countries including the ones in the brackets, and excluding Japan and U.S.A. have a known exploitable hydroelectric potential of more than 500,000 megawatts. Japan and U.S.A. have an exploitable potential less than 500,000 megawatts.

(f) **Traditional fuels:** countries known to consume more than 1000 petajoules (10^{15}) of energy through traditional fuels in 1991. Traditional fuels include wood, other plant products, dung, etc.

(g) **Wind and geothermal energy:** countries known to have produced more than 100 petajoules of commercial energy through these sources in 1991.

4. Use the world map provided in Appendix C, and mark the symbols in the appropriate places on it.

5. Using Table 4.3 and the picture of energy abundance that you have made, write a page describing source distribution. Explain what advantages a particular source confers on the countries which possess it. It would be interesting to return to this table after you do the activities in Section 4.9.

4.9 Resource and reserve

Just knowing that there is a 5 acre mango grove over on one bank of a wide uncrossable river does not make it a practical food for people on the other

Table 4.3: Distribution of energy sources in the world.

Source	Symbol	**Countries with abundance**
Coal		S.Africa, China, India, U.S.A., U.K., USSR (former), Australia
Crude oil		Iran, Iraq, Kuwait, Saudi Arabia
Natural gas		Iran, Russian Federation
Nuclear fuel (Uranium)		Namibia, Niger, S.Africa, Canada, U.S.A., Brazil
Rivers and waterfalls Hydro-electric potential		China, Japan(*), Canada, U.S.A.(*), Brazil, USSR (former) (Zaire, Indonesia)
Sunlight Solar energy potential		Guess.
Wood, biomass Traditional fuels		Nigeria, China, India, Indonesia
Waves, Ocean, temperature gradient in ocean		Guess or find out.
Wind, Geysers, hot springs (geothermal)		Philippines, Mexico, U.S.A., Italy

Note: Read the activity for abundance criteria.

bank. It is at best *a proved reserve in place* that can be used if the people are innovative enough to get across. Their innovation, say in building a bridge, or a canoe that carries people and mangoes, can, however, make the mango grove a *useful resource*.

Energy resources are like that mango grove. Resource estimates of non-renewable energy are based on geological, economic, and technical criteria. Resources are first graded according to the degree of confidence in their extent and location, based on available geological information. The technical and economic feasibility of their use is then judged. *Proved reserves in place* are the total resource that is known to exist in specific locations and in specific quantities and qualities. *Proved recoverable reserves* are the fraction of proved reserves in place that can be extracted under present and expected local economic conditions with existing technology. This is also known as the *available resource*.

Reserve estimates are not final measured quantities that stay constant over time. These estimates change as exploration, use, and technology advance, and as the economic conditions change. Keeping these points in mind, carry out the following activities to understand the difference between proved reserves and available resource or recoverable reserve.

1. The people of a certain village have found by echo-sensing that there is a larger body of water deep down in the earth, say, at a depth of 200 feet. However, they do not yet know a technology that can access this water. At this stage, have the people found a water reserve or, would you say it is a water resource for the village?

2. Based on the above examples, explain the difference between reserves of energy and an energy resource.

3. A company discovers coal in a far-away deserted place, say, in Antarctica. To get the coal to the nearest power plants, the company would have to -

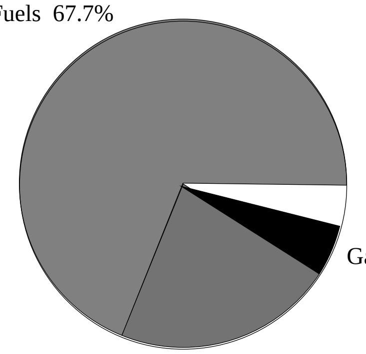
    - dig it up,
    - crush it,
    - load and transport by ship or other means to a train station,
    - unload it, and
    - transport it to power plants by train.

    Under what conditions does it make economic sense for the company to tap this coal? In other words, when does the reserve coal in Antarctica become a resource?

4. According to World Resources 1994-95 report [17], India has 131,254 million metric tons of proven coal reserves in place. Of these, 62,548 million metric tons are proven recoverable reserves. Explain the situation in terms of the the present availability and the capability to meet future demand of coal in India.

5. Write a paragraph on the role of science and technology in converting reserves into resources. Would science and technology also help increase reserves? Explain how this could happen with an illustrative example, real or imaginary.

Figure 4.4: Combination of energy sources in India in 1988.



6. India has a known Hydro-electric potential of 205,000 megawatts. The installed Hydro-electric capacity in 1990 was 18,864 megawatts. Write an essay describing the future possibilities this data indicates.

7. Are you aware of the issues thrown up by the Silent Valley Project in Kerala in 1970-72, and the major dams on Narbada river, namely Sardar Sarovar in Madhya Pradesh and Narbada Sagar in Gujarat. Would it be wise to exploit the entire Hydro-electric potential? Explain how the Government should go about it.

8. Imagine a scenario when we may be able to exploit the full potential of our water resources. What crucial advancement would make this a reality? Will it be a different perspective (view) of the problem, or a technological innovation? Justify your answer.

4.10 Energy sources in India

Figure 4.4 shows the combination of energy sources used in India in 1988 [17]. Study the figure and answer the questions below.

1. Describe the information in the pie chart in your own words.

2. Give a few examples of situations where solid fuels, liquid fuels, and gas fuel, where they are used directly to supply energy.

3. Name the fuels used to produce electricity.
4. Which fuel, according to the figure is maximally used in India to directly supply energy? Which is minimally used? Why do you think this is the situation?
5. Do you think this situation will change as India develops? Find the most recent data. Has the combination changed? Why?
6. Write a paragraph describing the factors that are likely to affect the combination of fuels used by people in any country.

In this and the preceding chapter, you have discussed the variety of energy sources available to humans. You have realised that it is not sufficient to have the resources located in a particular place. Because of various economic and technological realities, the control over the resource may not rest with local people. In the next chapter you will discuss the present patterns of use of commercial and other energy resources; of fossil fuels and renewable sources. You will also think about future strategies for energy use in keeping with certain criteria for selection.

Chapter 5

Energy consumption

5.1 Energy use and quality of life

As you have seen, that different energy sources began to be used at different times in history, and quantum jumps in energy use were hallmarks of development. Quantity of energy used is an indicator of the level of development. Wood is the energy source among the less developed. Electricity from coal, oil and natural gas, and nuclear power plants, in that order, and according to availability, satisfy the energy needs of the developed countries. Can development be measured? Certain economic indicators were used for the purpose, which have been replaced, in recent years, by quality of life. This encompass longevity, knowledge, and standard of living.

Per capita gross national product (GNP per capita) also serves as a measure of the relative development of nations. Quality of life, whatever be its measure, seems to be correlated with quantity of energy used. For instance, countries that consume more energy per person, generally, also have a higher per capita GNP. You will discuss this correlation in this section.

1. Table 5.1 gives the per capita energy consumption of some countries of the world, and their per capita GNP. Name the countries which use the highest and lowest amounts of energy per person. What are those values? Find out their populations in 1991. What were the total energy consumption of the countries in the year 1991?

2. Which countries in the table have the highest and lowest per capita

Table 5.1: Per capita energy use and per capita GNP of industrial and developing countries of the world. GJ = 10^9 Joules.

Country	**Per capita energy, GJ**	**GNP per capita US$ 1991**
Canada	325	20,740
Germany	187	19,204
Japan	140	26,824
Netherlands	212	18,858
Sweden	202	25,254
Switzerland	138	33,850
United Arab Emirates	656	22170
United Kingdom	157	16,606
United States	320	22,356
Sri Lanka	4	495
China	23	364
Greece	93	6530
India	9	330
Mexico	56	2971
Malaysia	45	2497
Mauritius	15	2380
Nigeria	6	305
Kenya	3	350
Pakistan	8	383
Indonesia	10	592
Iran	48	2274
Israel	88	12,293
Saudi Arabia	203	7893
South Africa	70	2543
Bangladesh	2	205
Bhutan	2	174
Ethiopia	1	123
Cambodia	1	202
Nepal	1	170
Sierra Leone	2	202
Mozambique	1	84
Tanzania	1	95

GNP? What are those values?

3. Suppose you now want to represent the data in the table in the form of a suitable graph. Which of the following types of graphs will be better suited to understand how the two variables are related? Justify your choice.

   (a) Linear x-y scatter plot: x and y scales varying linearly.

   (b) Log-linear x-y scatter plot: x-scale varying linearly and y-scale varying logarithmically.

   (c) Log-linear x-y scatter plot: x-scale varying logarithmically and y-scale varying linearly.

   (d) Log-log x-y scatter plot: x and y scales varying logarithmically.

   (e) Bar chart.

4. In the above activity, if you chose the scatter plot, either log-log, or log-linear with y-scale varying logarithmically, you know your graphs well. The best way to see the relationship between the two variables here, is a scatter plot. A linear scale will bunch up the points. Make a scatter plot showing per capita GNP on the y-axis, and per capita energy use on the x-axis. Choose a logarthmic scale on both x and y axes. Use the extreme values of both variables to decide the limits of your scales. Against each country in Table 5.1 write a unique abbreviation of two alphabets. Indicate the position of each country on the graph by putting its code alphabets near the corresponding point.

5. How does your graph look now? Fit a smooth line to the apparently scattered points in such a way that the sum of vertical separations of all the points from your line would be minimised. Your line should look approximately like an S-curve.

6. Mark a circle around the points in the plot corresponding to the first and last categories of your tabular values. You could also use 3 different colours of sketch pens, or highlighters, for good effect. Comment on what you *see* as a result.

7. The S-curve remaining the same, suppose that each of the countries increases its per capita energy use by a fixed amount, say 100 Gigajoules. Describe the change in per cpita GNP of the countries lying,

(a) near the lower left hand corner of the curve,

(b) in the middle, rising portion of the curve,

(c) near the upper right hand portion of the curve.

8. Note the location of the country with respect to your S- curve. How efficient are countries that lie to the left of the S-curve? And to the right of the curve?

9. Using the curve, write a persuasive article to the newspapers arguging that India needs to produce more electric power and should do so with greater efficiency.

10. Discuss, in groups of three each, the relation between energy use and quality of life. Discuss how every day habits vary with changing energy consumption. Different groups should look at the issue from the point of view of different countries. Each group presents its findings to the whole class. All participants should together write up a draft suggesting the policy for energy production and consumption in India.

5.2 World patterns in fuel use

Abundance, you have realised, is not the only factor that determines the use of an energy resource. In this section you will discuss the use patterns of the two major kinds of sources, namely, commercial fuels and traditional fuels, among different countries. You will also compare these with the resource patterns that you have discussed in Section 4.8.

Commercial energy is produced from sources like coal, oil, natural gas, and through hydroelectric power, geothermal, solar, wind and nuclear sources. Traditional fuels include fuelwood, charcoal, bagasse, and animal and vegetable wastes. Uses of commercial energy and traditional fuels are given in Table 5.2 for a few countries.

1. Could there be a reason in the context of commercial and traditional fuels for selecting the countries in Table 5.2? What could be that reason? (*Hint*: If you cannot guess, refer to Section 4.8).

Table 5.2: Commercial energy consumption and traditional fuel use in Petajoules (PJ = 10^{15} Joules), for select countries, in 1991.

Country	**Commercial energy, PJ**	**Traditional fuels, PJ**	**Abundance C or T**
Australia	3722	109	
Brazil	3551	2021	
Canada	8779	67	
China	27345	2018	
India	8011	2824	
Indonesia	1914	1465	
Iran	2906	29	
Iraq	531	1	
Italy	6768	48	
Japan	17384	10	
Kuwait	120	0	
Mexico	4834	248	
Niger	14	47	
Nigeria	691	1010	
Philippines	757	382	
Saudi Arabia	3121	1	
South Africa	2714	131	
U.S.A.	80839	916	
U.K.	9065	4	
USSR (former)	54730	792	
Zaire	73	365	

2. In the fourth column of Table 5.2, write against each country which kind of fuel — commercial **(C)** or traditional **(T)** — that it has abundant of. If it is rich in both kinds of fuels, indicate both.

3. Does the energy use pattern correlate with the fuel abundance for all the countries? For instance, does a country rich in nuclear or fossil fuel also use greater amount of commercial fuels than traditional fuels? List the countries which show a mismatch between abundance and use pattern. List the possible reasons for the mismatch. Compare your list with those of the other members of your group. How many reasons did you generate? Write a paragraph explaining the role of the following

Table 5.3: Quantity of different sources of energy used in the World and in India in 1991 and share of sources in USA. PJ $=10^{15}$ Joules

Source type	**World PJ**	**India PJ**	**India/World %**	**USA %**
Biomass/ wood	19942	2824		1.3
Coal	93689	5313		32.0
Oil	132992	1314		26.2
Gas	76275	397		28.3
Nuclear	22669	59		9.7
Hydro	8049	243		1.5
Geothermal/ wind	1261	0		0.8
Total (PJ)	354832	10151		

factors in explaining the mismatch. Cite appropriate examples, either pertaining to India, or any other country.

- The state of the country's economy.
- Its level of industrialisation (high, medium, low).
- Its own science and technology capabilities.

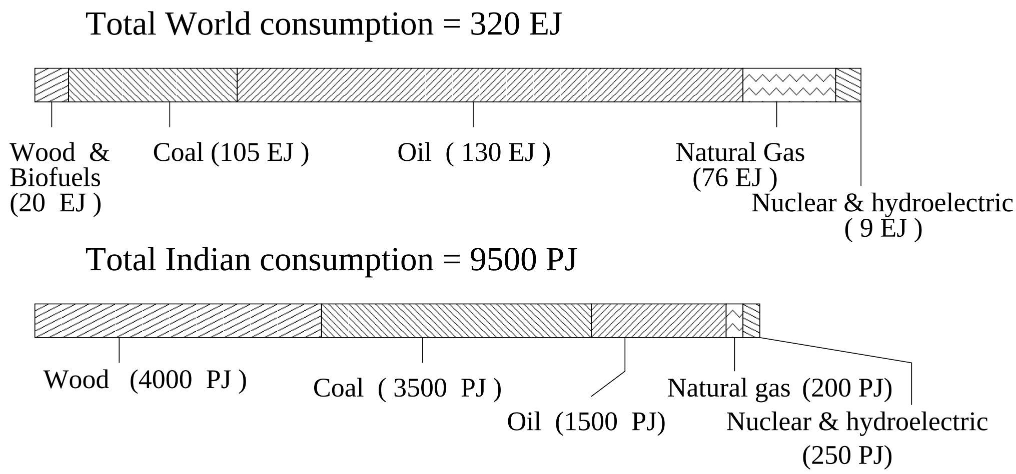
5.2.1 India vs World: proportions of energy use

You have seen in previous sections that industrial countries which have a smaller fraction of the world population consume a large proportion of the world's energy, while a majority of the population is energy starved. You will note and discuss the situation as it pertains to India in relation to the world. Table 5.3 gives the values in Petajoules (10^{15} joules) for different sources of energy used by the world as a whole, and in India [17]. The table should help you carry out the activities suggested below.

1. In the 4th column fill the percentage of the source used by India in relation to the World.

2. Given that the total energy used in USA in 1991 was 68852 Petajoules, what is the percentage of each source used by USA in relation to the World use of that resource?

Figure 5.1: Energy consumption by source in India, and the World — a bar chart



3. Figure 5.1 is a picture indicating the proportion of different sources consumed in India and the world in a certain year. However, it is not to scale. Draw 3 broad bars (about 3 cms broad), each about 15 cms or more in length. Let each correspond to 100% [17]. Indicate on each the proportional consumption of different sources within India, U.S.A., and the World. Use a different symbol for each source. Be creative about your choice of symbols to represent different sources. Be consistent for the 3 bars.

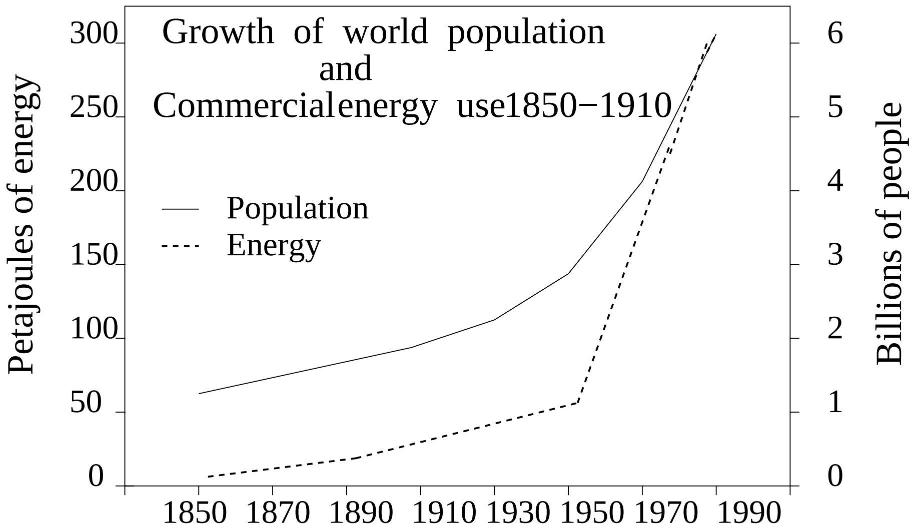
4. Every sixth person in the world is an Indian. Compare India's use of different energy sources with her share of population of the world.

5. India uses energy far below her energy generation potential. Which energy source will provide India with adequate energy at moderate costs?

5.3 Graph - energy use and population

There has been a rapid increase in population over the last century. This is discussed in the booklet titled *The Population Problem*. It would be interesting to ask whether the energy consumption has merely kept pace with

Figure 5.2: Population growth and commercial energy use.



the increase in population. Or, has energy consumption increased at a faster rate than the population? Figure 5.2 suggests an answer to this. Both the quantities are plotted in a same graph, as a function of years from 1850 to 1990 [17]. The commercial energy in the figure refers to energy from coal, oil, gas, nuclear power and hydro power. It excludes biomass energy — from fuelwood, crop waste, and dung. Study the figure and carry out the activities below.

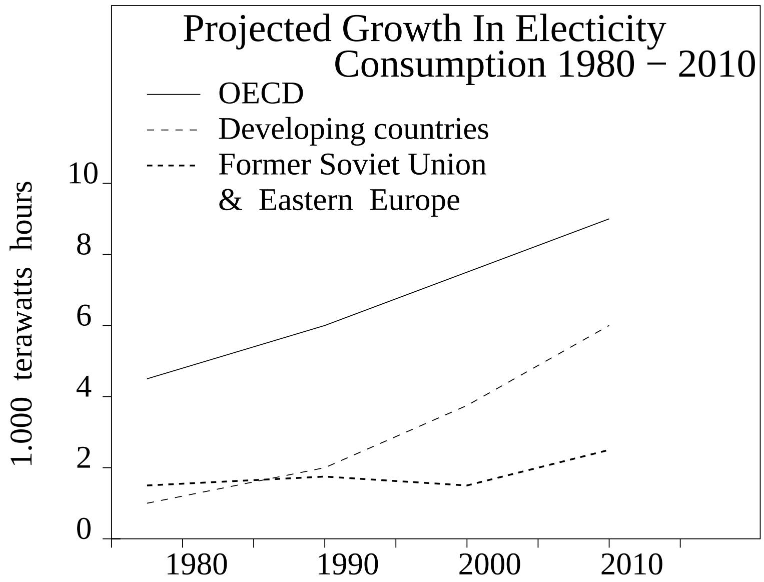
1. What was the population of the world and the amount of energy consumed in the year 1850? Give approximate estimates from the graph.

2. During what period have the population and energy increased at the same rate? What can you say about the increase of population and energy consumption after 1950?

3. Roughly, how many folds has the population increased from 1850 to 1990? Make a similar estimate about energy consumption.

4. Using Figure 5.2, make a table of per capita commercial energy use over the years. For each year marked along the x-axis, read off the energy

Figure 5.3: Projected energy consumption in the three regions of the world from 1980 to 2010.



consumption and population values and compute the per capita energy use.

5.4 Projections of energy use

Predicted in 1980, Figure 5.3 shows how commercial energy consumption was projected to increase from 1980 to 2010. The three plots indicate this for the OECD countries, developing countries and the transitional countries (see list in Appendix B). The exercises below will familiarise you with units of energy, estimating growth rates from a graph, and future electricity use.

1. According to the graph, how many folds was electricity consumption expected to grow in the developing countries from 1980 to 1990? What should it be in 1995? From a separate source of information, verify if this has actually happened.

2. Repeat the above activity for the OECD countries.

3. Compute from the graph the rate of rise of electricity consumption in developing countries during the 1990's.

4. Can you extrapolate the curves for 10 years beyond 2010? Can you extrapolate for another 40 years? Do you expect any problems with predicting electricity consumption over such long periods. Which are the parameters that would influence your estimate?

Predicting the future is never easy. You have to be able to estimate several important parameters that affect energy use. The following factors, among many others, could affect the energy consumption in a country:

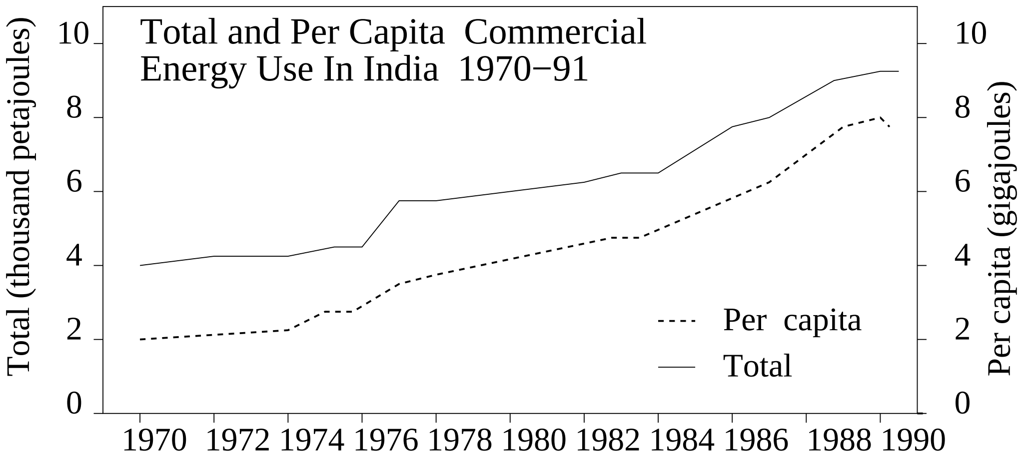
- discovery of new reserves,
- conversion of reserves into usable resources,
- technology levels in the country,
- technology access to the country,
- economic constraints of the country,
- the country's population size and growth rates, and
- changes in the efficiency of energy production systems.

Policy makers the world over are worried about the consequences of increasing energy use. They attempt to predict the possible future energy scenarios. One of their concerns is the increasing release of carbon dioxide into the atmosphere as a result of the use of fossil fuel use. You will encounter more on this in the book titled *Resources: Land, Air and Water*.

5.5 Energy use patterns in India

You have analysed the past, present and future patterns of commercial energy consumption in the world. You should also discuss the patterns for India.

Figure 5.4: Total and per capita commercial energy use in India from 1970 to 1990.



5.5.1 Growth in commercial energy use

The commercial energy consumption in India has grown at a faster rate in the last decade than ever before. Despite a growing population, the per capita consumption has increased too. It is still less than one sixth of the world average. India has large reserves of coal. Close to 60% of our present commercial energy supply comes from coal. Yet, about 20% of the country's primary energy needs are met through imports of crude oil and petroleum products. India is a net importer of energy. Figure 5.4 and the following activities throw light on the growing energy consumption in India over the years.

1. Compute from the graph the rate at which use of total energy grew in India during the following periods:
   - 1970–1976,
   - 1978–1984,
   - in the last decade.
2. Repeat the above activity for per capita energy use. Did your calculations for per capita use yield answers different from the values for total

energy? Did the per capita increase at a faster or slower rate than total energy?

3. You know that population of India has been growing all the time. From the graph can you tell whether the rate of increase in energy consumption has outstripped (been greater than) population growth rate? Use the graph and write a paragraph in defense of your answer.

4. Comment on the nature of the plots after 1989. What may have caused the changes during this period?

5.5.2 Sector-wise energy use

So far you have discussed how much energy gets used and the kind of sources that provide this energy. In what way does the energy get used? Which economic sector in our country uses more energy? This is what you will discuss in this section.

1. Many sectors of activity in the country require energy. Industry and agriculture are two such sectors. Name all the different sectors of activity.

2. Figure 5.5 gives the fraction of energy used by each sector (in per cent of total energy used) for India in 1991. What characteristics of energy use in India? Write a paragraph giving your ideas.

3. Do you think this is a static picture? How do you expect the pattern to change? Draw the pattern for the year 2000?

4. Table 5.4 gives share of electric power (utilities) consumed by different sectors in India in three years. Which sectors show an increase in their share of energy use? Which sectors show a decreased share?

5. What reasons can you think of for the rise in domestic share of electricity consumption? Note that the table shows only the share of electricity use. What must have caused the agriculture's share to increase? Why has the industry's share in electricity consumption decreased?

Table 5.4: Sectoral share of electric power consumption in India in 1980-81, 1990-91 and 1993-94.

Sector	**1980-81**	**1990-91**	**1993-94**
Industry	58.4	44.2	39.6
Transport (Railways)	2.7	2.2	2.4
Agriculture	17.8	26.4	29.6
Domestic	11.2	16.5	18.2
Others (Commercial, etc.)	9.9	10.7	10.2

6. Name some of the energy sources other than electricity used in each sector. For instance, coke is directly used in the steel industry. Agriculture uses several other energy sources, including tractors and draught animals. Will the values given in the table change in any way if we included other energy inputs?

7. Why is the information in Table 5.4 different from that given in Figure 5.5? Write a paragraph explaining the differences.

Many sources in a sector

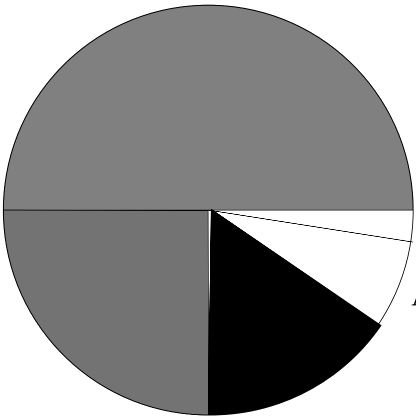
You may have realised in the last section that electricity is not the only kind of energy used in each sector. Table 5.5 shows the contribution of many kinds of energy sources in the agricultural sector [34].

1. What is the share of human energy in the farm sector? What proportion of the total energy in the farm sector is electrical energy? How would you estimate that from the table?

2. If the draught animal category were to decrease, which category is likely to increase? Discuss under what conditions a farmer may not prefer to use tractors.

3. In many countries, in particular, in African countries, women contribute a higher share of energy to agriculture. What reasons can you suggest for a smaller contribution by Indian women to farm energy? What can possibly change this situation?

Figure 5.5: Energy use sectorwise - India 1990-91.



4. Draw a *pie chart* to illustrate the information in Table 5.5.

5.5.3 Energy use: urban versus rural

The household or domestic sector is a significant consumer of energy in India. As you have seen before, the energy consumption in this sector varies from about 20% of the total consumption for all sectors on an average, to about 85% in rural households. In this section, you will ponder over the disparity in energy use between the rich and the poor, and between the rural and urban households.

A combination of commercial and non-commercial fuels is used in households to satisfy the energy needs. Commercial fuels include, soft coke,charcoal,kerosene, electricity and liquefied petroleum (LPG) The last two are rarely used in rural households. Non-commercial fuels include firewood (fuelwood), vegetable wastes and dung cake. As you can readily guess, the share of commercial fuels is larger in urban households than in rural ones. Table 5.6 gives the fuel used by urban and rural households of different income categories [34]. The values are given as percentage share of each category of fuel in terms of energy. Analyse the table through the activities suggested below.

Table 5.5: Contribution of various energy sources to the agricultural activities in 1991–92.

Source of power	**Percentage of total**
Human, males	7.32
Human, Females	2.08
Draught animals	25.76
Tractors	23.80
Power tiller	0.44
Diesel engines	14.04
Electric motors	25.32
Combines	1.24

Table 5.6: Commercial (C) and noncommercial (NC) fuel* used by urban and rural Indian households of different income categories.

Annual household	**Rural**		**Urban**	
income in Rs.	**C**	**NC**	**C**	**NC**
Up to 3000	4.2	95.8	37.3	62.7
3000 to 6000	4.6	95.4	56.8	43.2
6000 to 12,000	7.6	92.4	71.9	28.1
12,000 to 18,000	7.6	92.4	76.5	23.5
18,000 and above	10.1	89.9	82.7	17.3
Average (A)	5.1	94.9	58.3	41.5
Difference (D) between poorest and richest				
Percentage difference $= D/A$				

Note:* - Fuel use given in percentage share of total fuel used in 1991

1. Find the minimum and maximum in each fuel category, namely, commercial and non-commercial, for rural and urban households.
2. Of all the groups of people, who uses maximum amount of commercial energy? Who uses the minimum amount of commercial energy? Who uses mostly renewable energy sources? Who uses least amount of renewable sources?
3. Find the difference in usage between the poorest and richest in usage of each category of fuel and fill the second last row. Calculate the percentage difference using the formula given below, and fill the last row with these values.

$$Percentage\ difference\ in\ usage\ =\ 100 \times \frac{Difference\ in\ usage}{Average\ usage}$$

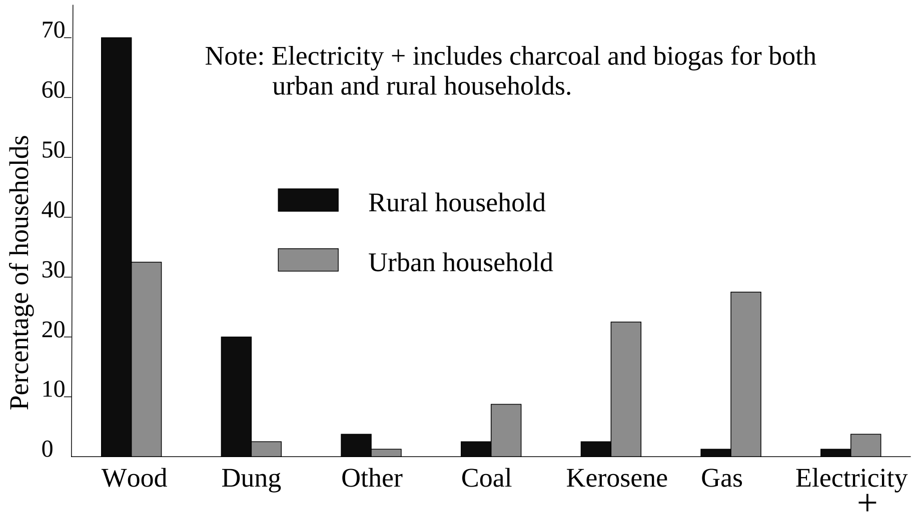
4. Comment on the pattern of numbers in the last two rows. Write a page on your thoughts about the difference in fuel use by the rich and the poor. Explain the possible cause and effect of such differences.
5. Should there be a national attempt to reduce the above differences? Justify your answer. If you said the differences should be reduced, suggest ways of doing so.
6. Figure 5.6 gives a picture of the different cooking fuels used by urban and rural households [1]. Write a paragraph explaining what you understand from the picture.

5.5.4 Expenditure on energy: urban vs rural

You are now familiar with the kind of energy used by the rich and the poor in our country. You have also seen the disparities in the use of commercial and non-commercial fuels and in the special category of cooking fuels. It may be interesting to see how much the rich and the poor in India spend on their energy needs.

Figure 5.7 shows the amount of money that a person spent per year (per capita per annum) in the urban and rural areas [17] on energy, travel, various goods and facilities. When all the categories are analysed together, a pattern of spending emerges. Durable goods include electrical and non-electrical

Figure 5.6: Distribution of households by type of cooking fuel used in 1991.



equipment, electronic goods, motor vehicles and other transport equipment. The values pertain to 1989-90. In this figure, households are categories according to their annual earning into 3 broad socio-economic groups separately in rural and urban areas. The groups are described below.

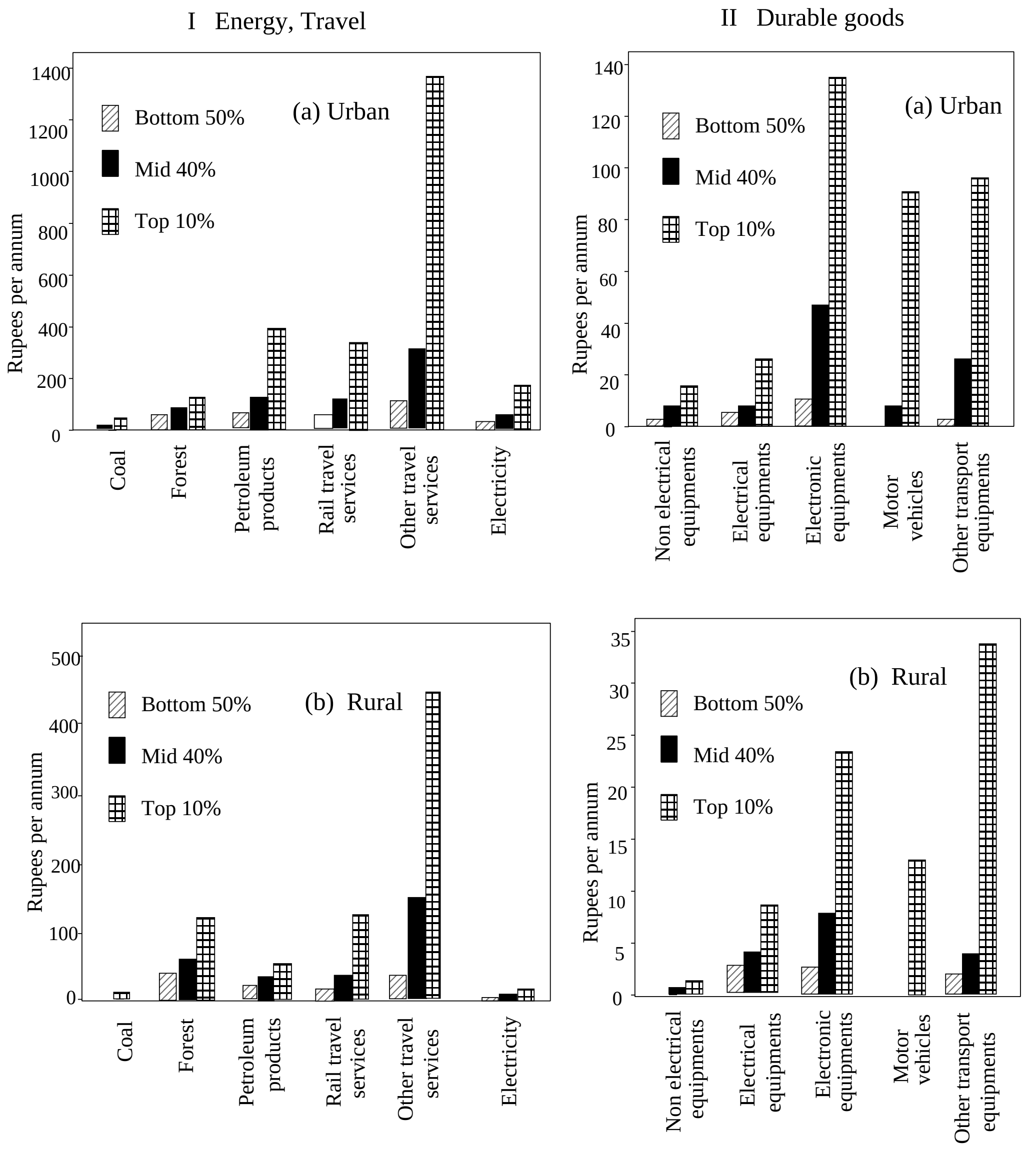
The Poor - For this analysis, the poor constitute the bottom 50% in annual earning. In 1989-90, the annual household income of about 59% of the Indian population was less than Rs.12,500/-. Landless persons, isolated tribal groups, and urban slum dwellers in search of jobs are included in this category.

The Middle class - They constitute the middle 40% in annual earning.

The Rich - They include the highest 10% in annual earning. For the urban population, this would consist of households earning more than Rs.40,000/- per annum in 1989-90.

1. Which durables do the urban middle class spend the most on? Which do they spend the least on? How does the pattern change in the case of rural middle class?

Figure 5.7: Per capita expenditure of Indian rural and urban households in 1989-90 on (I) Energy and travel, and (II) Durable goods.



2. Who spend the most on private transport vehicles and equipment? Hence, can you argue who must depend most on public transport? Study the spending pattern on vehicular transport, and use this information to write a page on the merits and demerits of privatising the transport system. Who should it cater to? And How?

3. Assume for convenience that about 30% of Indian population is urban. This is close to the value for Maharashtra State in 1991. The population of India by the 1991 census was 848 million. Based on the per capita values given in the chart, calculate the total spending by the 6 categories of people on non-electrical and electrical equipment. Tabulate your values in an appropriate table.

4. Now study the spending patterns for energy and travel. Coal, petroleum products, forest produce and electricity constitute spending on energy. Other travel services would include bus, motor vehicles and other private and public transport services. Relate the spending on durables with the expenses on electricity and travel.

5. Using the population numbers, and urban to rural ratio given in item 3 calculate the total spending of the 6 categories on the different types of energy and travel services. These would include, coal and forest fuels, petroleum products, electricity, rail travel, and other travel. Tabulate your calculated values.

6. Write a paragraph analysing the contents of your table in terms of the patterns of spending. On the basis of your calculation, keeping in mind that both the total population and the proportion of urban population are steadily increasing, predict the spending patterns in the year 2000.

7. Subsequent to the announced liberalisation, India is lowering her trade barriers with other countries in a phased manner. This has already begun to attract foreign and multinational companies to set up their factories here. They invest their money in producing goods, facilities and services. The profits to be made by selling their goods and services within the country is related to the spending patterns of the Indian people. Judging from the two tables you have generated in the previous activities , which of these areas seems most attractive for investment? Is that actually the case? Find out. If there are disparities, try to explain them.

Table 5.7: Energy (in terms of power) demand (Dem) and supply (Sup) in the different regions of India, from 1991 to 1995

Region	**Energy in billion kilowatt hours**							
	1991-92		**1992-93**		**1993-94**		**1994-95**	
	Dem	**Sup**	**Dem**	**Sup**	**Dem**	**Sup**	**Dem**	**Sup**
North	87.1	82.0	92.2	87.0	97.4	90.5	104.7	97.1
West	89.4	85.2	93.7	88.6	99.6	95.7	110.3	106.0
South	75.0	67.3	79.9	71.8	84.7	77.5	93.0	85.6
East	34.1	28.9	35.8	29.4	37.9	32.5	40.3	35.1
North-east	3.4	3.1	3.7	3.1	3.7	3.3	3.8	3.5
All India	289.0	266.4	305.3	279.8	323.3	299.5	352.3	327.3

8. How is energy consumption related to the the spending patterns depicted in your two tables. Write a paragraph on the role of energy in producing and using durables and in transport.

5.5.5 Power: demand and supply

Demand for electrical power in a country like India is bound to increase for many decades to come. Both increase in population, and increase in GNP would cause this. In this context, you may want to discuss whether our energy production meets existing demands. The following activities will spur you on. Table 5.7 gives the energy demand and supply in billion kilowatt hours in 4 consecutive financial years from 1991 to 1995 [34]. Study the table and discuss the issues raised below.

The states which constitute the different regions are given below.

North Haryana, Himachal Pradesh, Chandigarh, Delhi, Jammu and Kashmir, Punjab, Rajasthan, Uttar Pradesh.

West Gujarat, Madhya Pradesh, Maharashtra, Goa.

South Andhra Pradesh, Karnataka, Kerala, Tamil Nadu.

East Bihar, West Bengal, Damodar Valley Corporation, Orissa.

North-east Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura.

1. Which of the regions in Table 5.7 show the highest demand in 1994-95? Has it been so over the last 4 years? What factors may have contributed to this demand? In general, what conditions increase the demand for energy? List them. Discuss the lists of the whole class.

2. Which region shows the greatest absolute difference between demand and supply of energy? Which region shows the greatest percentage shortfall (difference between demand and supply of) in energy? You can calculate this by the formula,

$$Percentage\ shortfall\ =\ 100 \times \frac{Demand\ -\ Supply}{Demand}$$

3. Draw a bar chart to illustrate how the demand and supply has varied over the four years in the region in which you live, say the Western region.

4. Mark the regions on a map of India to pictorially indicate the energy demand pattern. The map is provided in Appendix D. Mark on a separate map, the energy supply in different regions. Is energy demand an indicator of development in the region? Justify your answer. Refer back to Section 5.1 on quality of life.

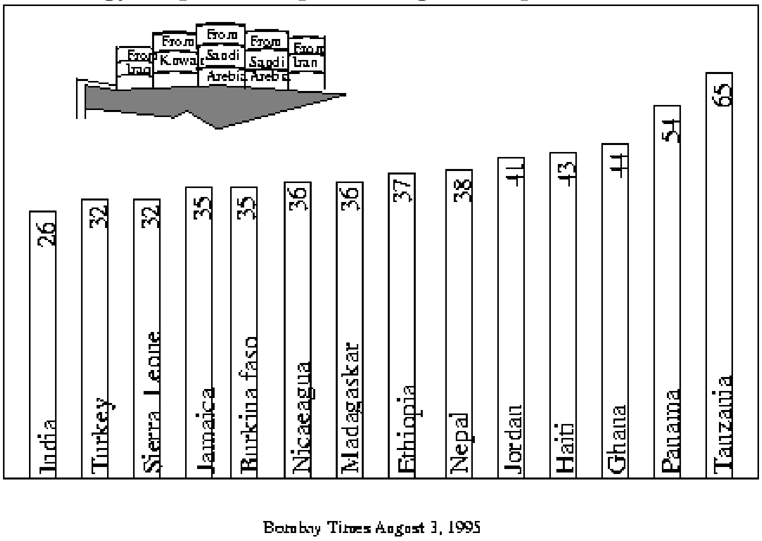
5.6 Fuel imports

You have seen in the previous section that we have a shortfall of energy in every region of our country. We reduce some of this shortfall by energy imports. Besides, our industrial activity and domestic fuels requirements need oil and natural gas, of which we have scant resources compared to our needs. Almost all the cooking gas (LPG) used in our country is imported. We also import a large proportion of petrol used.

Figure 5.8 shows how much of foreign exchange earned through exports is spent on importing energy resources in various countries including India. The figure has been adapted from the *Bombay Times, August, 3, 1995.*

1. What energy sources do we import? What can we do to reduce our total energy import? List the circumstances under which the energy imports in our country will become a smaller fraction of exports?

Figure 5.8: Energy imports as percentage of exports for various countries.



2. Are our our energy imports related in any way to our export earnings? In other words, would changes in energy imports affect our export earnings?

Given below are energy scenarios in 4 different hypothetical countries. Read them carefully, and think about the questions raised below.

- A country INDUS imports energy resources, and uses it to generate electricity efficiently for its industrial parks. The industrial parks produce export oriented goods of high quality at competitive prices. Their export earnings increase with time till they reach a steady value.
- A country DOMO imports domestic fuel, like LPG. The country which is industrialising fast, increases its exports too. As its economy flourishes, people's life styles change. More households shift from wood and traditional cooking fuels to LPG.
- Country SCITECH, is initially high in import of energy. It invests in science and technology innovation to use its existing energy resources more efficiently. Over a decade or two the country struggles hard and its exports even decrease for a while. The economic situation does not look

too bright. However, with persistence and perseverance, the scientists make a breakthrough in using the alternate energy sources efficiently.

- Country ECOTS starts a mission-oriented approach to reducing resource wastage and increasing energy efficiency in every sector of operation, including the domestic sector. It improves generation efficiencies, and reduces transmission losses. It encourages local initiatives in local energy use. The schemes include biogas generation, higher efficiency stoves and lamps, and use of waste steam from boilers and kilns for energy generation from waste.

Write a comparative essay on the relative performance, in terms of energy and quality of life, of each of the four countries. Mention the advantages and disadvantages of their approaches. Which do you think is a better option? Any why? Write an essay stating and justifying the best energy policy option for India. Do you feel you are now able to link the different issues raised in this book? If you do, then you have successfully used this booklet. And what is even more important, you are a thinking energy-conscious person!

Chapter 6

Energy conservation

It is almost a fad to talk and write about *energy problems*. Decreasing availability of fuel is not a new problem, though it affects many more facets of life today than it ever did before. Consider the following scenarios over a couple of thousand years ago [3] [4].

6.1 Crisis and response in ancient times

Greece, about 2500 years ago had warm summers and cold winters. Wood was their primary source of energy for warming their homes in winter. By 5th century BC, fuel shortages were acute. The Greeks *imported* wood from farther away, and depleted their olive groves, thus destroying a valuable resource. Within a century, the use of olive wood for fuel was banned in Athens. At about the same time, it appears from archaeological studies, that they also began to design their homes in such a way as to avoid direct sunlight in summer, while in winter, sunlight would provide the warmth.

The Romans also used solar energy, but in more innovative ways. They used glass windows to increase effectiveness of heating and raised food in greenhouses in winter. In order to protect a person's right to solar energy, they even established suitable laws. For instance, it was illegal to construct a building that shaded another's.

The Indus valley civilization was the first one to use fire-baked bricks, in contrast to the sun-baked ones of the Egyptian and Sumerian civilizations. The Indus people also smelted copper. One theory has it that they used up all

Table 6.1: Criteria for integrated energy management.

1. It can last a long time.
2. Aggressive energy efficiency can be mandated and monitored.
3. It is economically viable.
4. It does not damage the environmental quality of the place.
5. It will help in economic development.
6. It will provide the most efficient combination of source, technology and end-use, satisfying the Second Law of Thermodynamics.

the nearby forests in the process, thus degrading the land around them. This may have caused the rivers to meander, and floods that may have destroyed the civilization.

Compare and contrast the situations 2500 years ago and now. List your points and discuss them in the class.

Integrated energy management

You have discussed that a suitable mixture of technologies and sources will have to be used to provide for all the energy needs of both, the developing and industrialised countries. It would be educative to draw up a set of criteria to decide on suitable energy options.

A set of possible criteria that will ensure that a particular set of energy sources can be sustained without causing harm to people and the environment is listed in Table 6.1. List the energy sources and related technologies that you think satisfy these criteria for your city, town, or district. Justify your choice. Discuss your list in the class. Draft an energy plan for your area and send it to the concerned State Energy Development Agency (Maharastra Energy Development Agency, Gujarat Energy Development Agency, etc.).

6.2 Energy audits

"Switch off the lights when not in use" is an advice that will not only save energy, but also money. This advice is relevant for all commercial energy used. This is also true, though indirectly, for all resources used by us. You

might then ask, how much would we save, anyway? You will discover for yourselves through an *energy audit* of your homes and school/ institutions. As a first step, you will have to survey the energy used in your homes and school/ institutions, averaged over a month or year. Then, you will have to analyse where you can reduce without affecting your productivity of people. Then you will have to persuade other people concerned.

6.2.1 Preliminary listing

The following activities will help you focus on the necessary information.

1. List the lighting, heating and cooling devices used in your home and school/ institution.

2. List the energy sources (electricity, wood, solar, wind ..) used for lighting, heating and cooling in your home and school/ institution. Have the sources changed over the 50 years? Do you think they could change in the next decade? If yes, in what way?

3. Estimate the total money spent on lighting, heating and cooling in your home and school/ institution. Does the cost vary over months?

4. Energy efficiency ϵ of a device is defined as,

$$\epsilon = \frac{\textit{energy used by machine in given time}}{\textit{work done by the machine in same time}}$$

   Do you know of any effort made by users (customers), or energy suppliers, like power stations, and manufacturers of energy-using devices, to improve energy efficiency of devices used in homes? Describe those efforts. Do you think it would help to make such efforts? Estimate the monthly savings effected by the above exercise.

6.2.2 Survey of home and institution

In this activity, you will list the various items that consume electricity in your home and calculate their consumption.

1. List the number of each of the following categories of electrical items.

(a) Lights,
(b) Cooking appliances,
(c) Fans and other cooling devices,
(d) Heating Devices (Geysers),
(e) Helpmates (washer, cleaner, iron, computer...),
(f) Entertainment aids.

2. Find the wattage of each of the above items, usually marked on them, or written in an accompanying brochure.

3. Estimate the average number of hours each item is used in a day / in a week / in a month.

4. Find total monthly consumption of energy in units of Kilowatt-hours (Kw-h)= $kilowatt \times hours.$

5. Find the 'cost per unit of electricity' from your electric bill. You will see that this varies with the amount of electricity (in number of units) consumed. What is it for your bill?

6. Tabulate all your data and your calculations. Table 6.2 gives a rough format. This is your estimate of your household's monthly electric bill.

7. Compare this estimated monthly cost of electricity with your actual monthly electric bill, averaged over the last 12 consecutive months. Explain the difference if it is greater than 10% of the actual bill.

8. It is sometimes necessary to increase energy use to have an efficient and productive working environment? Justify. Refer to the exercises in Section 5.1.

9. Analyse the consumption under each category in terms of whether you think there is scope for increasing or decreasing the consumption and cost. Write against each item how you need to change the use of an item.

10. Make a plan of action to implement changes in consumption that you want to effect in your home. Make your plans in consultation with your parents and elders and siblings. Tabulate your report, analysis and action plan in a table. Table 6.3 is a possible format.

Table 6.2: Monthly electricity use and expense at home or institution.

Category	**Appliance**	**Rating Watts**	**Use in hrs/ mnth**	**Use Kw-h**	**Cost Rs.**
Lighting	Tubes Bulbs Others				
Subtotal					
Cooking Appliances (for home)	Toaster Fridge Others				
Subtotal					
Cooling	Fans Coolers				
Subtotal					
Helpmates (for home)	Geyser Iron Others				
Subtotal					
Entertain- -ment, Education	TV/VCR Stereo/CD Computer Others				
Subtotal					
Total					

11. Carry out all the exercises listed above for your school/ institution. Make your plans in consultation with your school/ institution authorities – Principal and senior teachers. What differences did you find in the two places? In which case was there more scope for improvement? Did this cause an overall increase or decrease in energy use?

12. Suggest some practical, cost-effective ways of using the solar energy effectively in your home and school/ institution.

Table 6.3: Analysis and action plan for electricity consumption at home.

Category	**Brief analysis report**	**Future action plan**
Lighting		
Cooking (for home)		
Cooling		
Helpmates (for home)		
Entertainment/ Education		

6.2.3 Transport – energy guzzlers

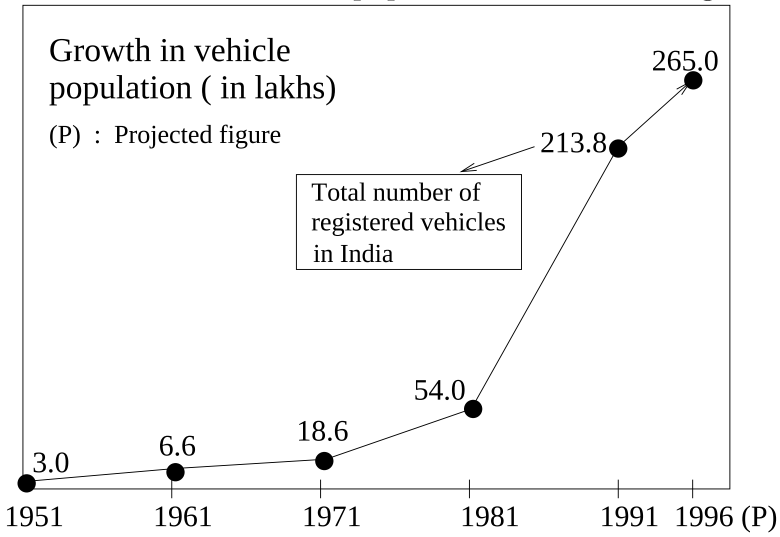
Transport is one of the essentials of modern living. Figure 6.1 gives the rate at which the number of vehicles on our roads is increasing. You will discuss the pollution consequences of this in another booklet. Here, you will consider the energy consumption by vehicular transport, and suggest workable options.

1. Write a page describing the load on the energy resources of the country due to the scenario depicted in Figure 6.1.

2. Of the fossil fuels, natural gas appears to be the cleanest one. It gives maximum energy output with a minimum emission of pollutants [25]. Compressed Natural Gas (CNG) cylinders are already being fitted on few taxis in Mumbai. Talk to some taxi owners and list the advantages and disadvantages of using CNG.

3. Refer Table 5.1 in Section 5.1 and the graph you have drawn in that activity. Compare the per capita energy use and per capita GNP of Sweden and USA. Which country uses fuel more productively? Justify in terms of the numbers in the table or your graph. Read the following

Figure 6.1: Growth of vehicle population in India during 1951–96.

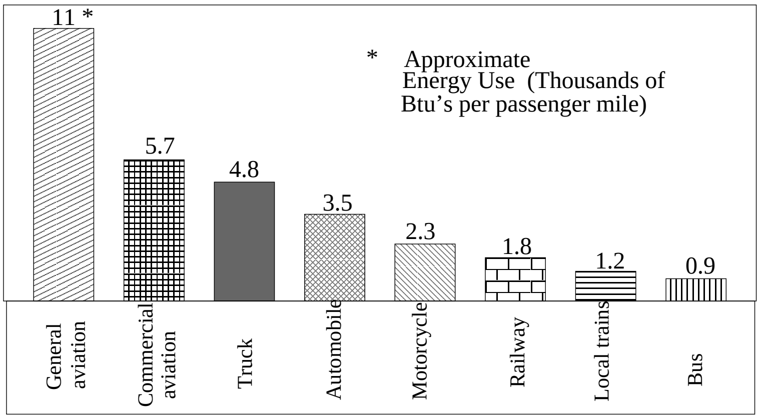


report and write a page suggesting some transportation options for the Indian situation. [35].

> Overall, Swedes use approximately one fourth the energy for transportation that Americans do. Some of this fuel saving results because Sweden is much smaller than USA, and the average distance between cities is considerably less. However, this difference alone cannot account for the wide discrepancy in energy consumption; in addition,
>
> (a) people in Sweden frequently walk or use bicycles for short trips;
> (b) mass transit is used more frequently;
> (c) on the average, Swedish cars consume considerably less fuel per kilometre than American cars do.

4. Figure 6.4 gives the approximate (lower-end) energy efficiency of some passenger transportation [22]. Study the figure and list the options for passenger transportation at individual, city, state and national levels. Remember to include walking and bicycles, which are not included in the figure for obvious reasons.

Figure 6.2: Energy efficiency of passenger transportation.



5. On a map of your city, town or district. Mark the following locations;

   (a) your home, and homes of relatives and friends,

   (b) most frequented stores and shopping places,

   (c) place of work of your family members,

   (d) the location of schools/ institutions you and your brothers and sisters attend,

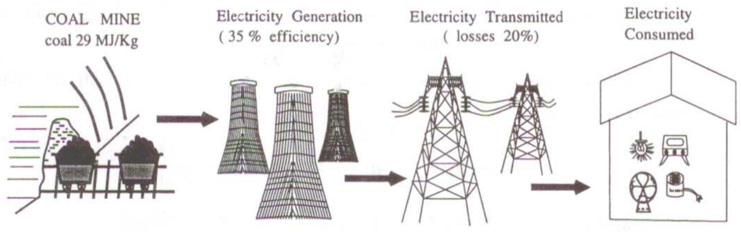
   (e) other places which you or your family frequents.

6. For each place above, estimate the distance from your home.

7. Estimate the total distance traveled by each member of your family on a typical working day and on a typical holiday. Find the average distance traveled by each member over a week/ month.

8. In each case, note the means of transport used - car, taxi, autorikshaw, bus, train, motorcycle, scooter, bicycle or walk. Estimate the distances traveled using each type of transport by your whole family, on an average per month. Based on your knowledge of transports and their efficiencies, do you think there is scope for conserving energy, saving time and economising? What are the limitations?

Figure 6.3: Coal energy: from the mine to electicity in homes.



9. Using the above survey of your family's transport needs, survey the transportation used by other people in your neighbourhood, with similar and dissimilar backgrounds and vocations.

10. Analyse suitably the survey collected by your whole class. Discuss the results in the class.

6.3 Energetics: a practical situation

Consider this situation. You have guests at home. All you have is an electric pot of 1 Kilowatt rating. It can contain enough water for 4 cups of tea. You heat the water for 3 minutes and water boils. Estimate the amount of coal from the mine that must have been used up in the thermal power plant to give you enough energy to make 4 cups of tea. Make reasonable assumptions as you need to. To solve this problem, you need to know.

- the average energy content of the coal available in India,
- what happens to the coal from the mines until it is transformed into heat energy in your cup of tea,
- quantitative estimate of the losses at each stage.

Figure 6.3 illustrates the stages in the life of coal energy from its birth in the mine to its transformation into the electricity consumed in homes and offices. Use the information in the figure to make your estimation and hazard an intelligent guess! If you are still stuck, follow the steps given below.

1. There is a neat trick that you learnt in your school Algebra that will be useful here. Let x be the amount of coal from the mines that you need for the tea. Its heat content, at 29 MJ/kg, would be 29x MJ.

2. Transport and mining use up 10% of energy. Hence energy reaching power station would be $29x - (0.1 \times 29x) = 29x - 2.9x = 26.1x\ MJ$.

3. Electicity is generated at 35% efficiency, that is $0.35 \times 26.1x = 9.14xMJ$ is generated.

4. Transmission losses amount to 20% of electrical energy. The energy transmitted is $9.14x - (0.2 \times 9.14x)$, which is $9.14x - 1.83x$, or $7.31xMJ$.

5. The energy used up by the heater to heat the 4 cups of tea, which is $7.31x\ MJ$ can also be calculated in another way. You know the power consumed from the rating of the heater (1000 watts), and the time for which it was run (3 minutes). Hence, energy consumed = $1000 watts \times 180$*(secs)* which is 180, 000 joules, or 0.18 MJ.

   That gives $7.31x = 0.18$. Therefore, the quantity of coal can be estimated in kg as,

   $$quantity\ \ of\ coal\ in\ kg = x = \frac{0.18}{7.31}$$

   This works out to about 25 grams. Was your guess close?

Select other familiar situations of elecricity use and estimate the coal used.

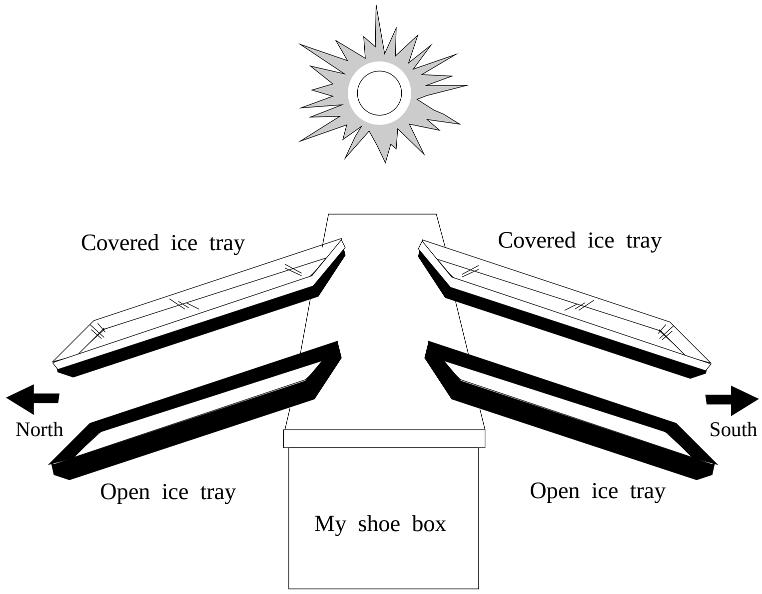
Is there any scope in these situations for increasing the efficiency of fuel use to deliver a greater amount of energy and work from the same amount of resources? Discuss the importance of this issue in the class.

6.4 Experiment and find out

This section invites you to try out two simple activities with solar energy [35]. You may carry these out in convenient groups of four. You will need the following items:

- Four ice cube trays (freezer trays), without the dividers, or equivalent shallow trays,

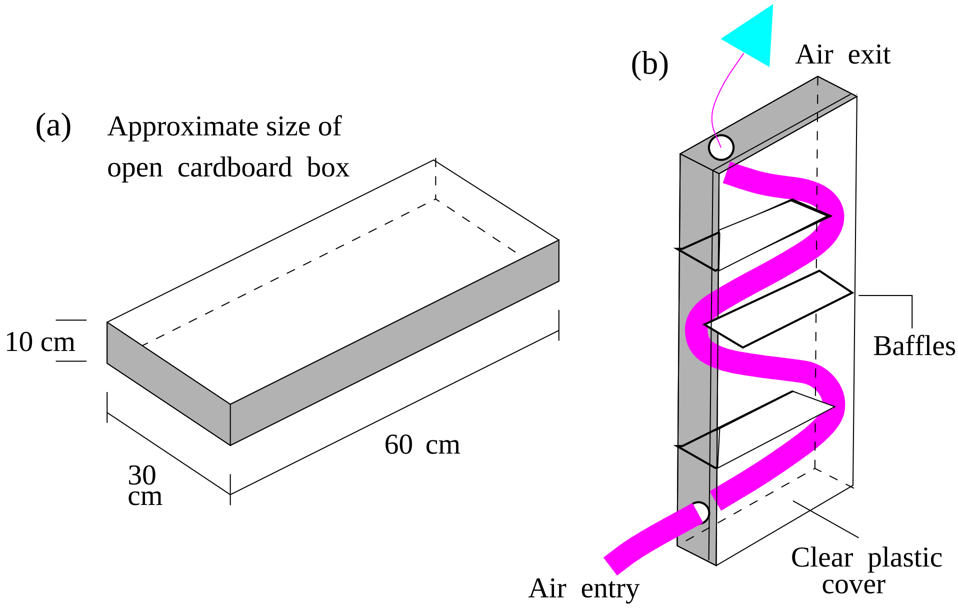
Figure 6.4: Schematic of solar collector set-up.



- A shoe box, or some prop,
- One medium sized – 30 cm wide, 60 cm long, 10 cm deep cardboard box, which you can get at an electricals, or grocery store,
- Additional cardboard, 3 pieces of about 25 cm by 10 cm,
- Clear plastic paper, to cover two trays, and a box face of 30 cm by 60 cm.
- Two large rubber bands, or string, to go around the tray mouth,
- Some black oil paint,
- Strong sticking tape, or thick paper and glue, sharp blade.

1. Take the 4 identical trays and fill each with the same amount of water, until each is about two thirds full. Set all 4 trays in the freezer compartment until the water is frozen. Cover 2 of the trays with plastic

Figure 6.5: A solar air heater.



paper, and seal around the edges with string or a rubber band. Replace the trays in the freezer and let them stay overnight.

Next day, say around 10 am, prop the 4 trays on waterproof surface, in an open place as shown in Figure 6.4. Place a covered and an open tray are tilted to the south, and the other pair tilted to the north. Let them sit in the sun, and note in which tray ice melts first. Which design was the most efficient collector of solar energy? Plan and carry out an experiment to test the effect of insulating the trays with thermocol or dry crumpled newspaper.

2. Take the medium sized cardboard box, and remove the top cover (30 cm by 60 cm). Cut two holes, each 3 cm in diameter – one at one end of the long side, and another at the opposite end on the 10 cm by 30 cm side, as shown in Figure 6.5 (a). Tape the additional cardboards within the box, along the length of it, as shown in Figure 6.5 (b). These are called baffles. Paint the inside surfaces of the box with black oil paint. Cover the open face with plastic. Place the box upright as in the figure. Set your solar heater in the sun and leave it there for about an

hour. Measure the air temperature at the lower inlet port and the upper outlet port. How well does your heater work? Explain the purpose of the baffles, the black paint and the clear plastic.

Whenever a resource is used, some waste is unavoidable. Inefficient processes create more waste than efficient ones. Efficiency is limited by the Second Law of Thermodynamics. Hence, reduced, efficient usage is the best way to conserve resources. This is usually accompanied by the bonus of waste minimisation and improved economy. Even so, the non-renewable resources will run out sooner or later. Hence, science and technology research in the country needs to focus on improving efficiencies of energy production and use- from power stations to appliances and automobile engines. At the same time we need a missionary approach in the efficient use of renewable resources and in economising. India is well endowed with such resources – and potential human resources like you.

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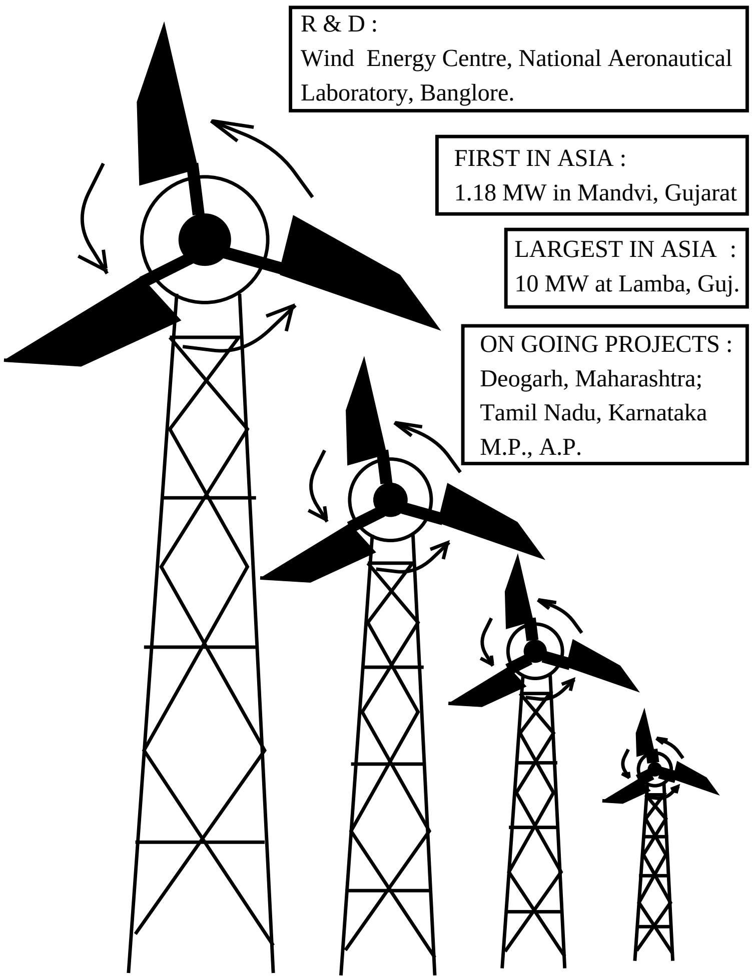
WIND - FARMS


R & D :
Wind Energy Centre, National Aeronautical Laboratory, Banglore.
FIRST IN ASIA :
1.18 MW in Mandvi, Gujarat
LARGEST IN ASIA :
10 MW at Lamba, Guj.
ON GOING PROJECTS :
Deogarh, Maharashtra;
Tamil Nadu, Karnataka
M.P., A.P.

Appendix A

Energy units

When large amounts of energy are involved, it is convenient to express them in multiples of thousands of Joules. They have convenient names and add on as prefixes to the energy or other units. Some of the more common ones used in expressing energy are given in Table A.1.

Some commonly used units for expressing energy and power are given in Table A.2. The table also gives the factor that will convert it to joules or other units.

Table A.1: Prefixes and orders of magnitude

kilo	K	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}
peta	P	10^{15}
exa	E	10^{18}

Table A.2: Familiar energy and power units, their conversions.

Energy & power units, conversions		
Unit	**Conversion Factor**	**New Unit**
1 Joule	$= 10^7$	ergs
1 Petajoule	= 163400	UN Standard barrels of oil
	= 0.0009478	Quads
1 Quad	$= 947.8 \times 10^9$	Btus
1 Btu (British thermal unit)	= 1055	joules
	= 252	calories
1 calorie	= 4.18	joules
1 Food calorie	= 1000	calories
1 therm	$= 1 \times 10^5$	Btu
	$= 1.055 \times 10^8$	joules
1 mtce	$= 2.55 \times 10^{13}$	Btu
(million tons of coal equivalent)	$= 2.69 \times 10^{16}$	joules
1 mtoe	$= 4.25 \times 10^{13}$	Btu
(million tons of oil equivalent)	$= 4.48 \times 10^{16}$	joules
1 barrel of oil (42 US gallons)	$= 5.62 \times 10^6$	Btu (approx.)
	$= 5.92 \times 10^9$	joules (approx.)
1 eV (electron volt)	$= 1.6 \times 10^{-19}$	joules
1 MeV (million electron volts)	$= 1.6 \times 10^{-13}$	joules
1 Btu per hour	= 0.293	watts
1 horsepower	= 746	watts
1 kilocalorie per hour	= 1.167	watts
1 Watt–hour	= 3600	joules
	= 3.52	Btu
1 kW–hour	$= 3.6 \times 10^6$	joules
	= 3416	Btu

Appendix B

Categories of countries

In reference to this book, **industrial countries** are the countries belonging to the Organisation for Economic Co-operation and Development (**OECD**). Names of these countries are given in Table B.1.

There are many countries that have recently — within the last decade - – either been born as independent countries, or have had a major change in government. These countries, of Eastern Europe and the former USSR, are going through a rapid transition in economic state. The names of these **transitional countries**, whose economic status is yet unclear, are listed in Table B.2.

All the countries not included as either industrial or transitional countries are called **developing countries**.

Table B.1: The OECD countries: a list

Australia	Greece	Norway
Austria	Iceland	Portugal
Belgium	Ireland	Spain
Canada	Italy	Sweden
Denmark	Japan	Switzerland
Finland	Luxembourg	U.K.
France	the Netherlands	U.S.A.
Germany	New Zealand	

Table B.2: Transitional countries: a list

Albania	Georgia	Poland
Armenia	Hungary	Romania
Azerbaijan	Kazakhstan	the Russian Federation
Belarus	Kyrgyztan	Tajikistan
Bulgaria	Latvia	Turkmenistan
Czechoslovakia (former)	Lithuania	Ukrain
Estonia	Moldova	Uzbekistan

1. Indicate against each country in Table B.1, whether the country lies above the Tropic of Capricorn (A) or below it (B). How many of the OECD countries lie below the Tropic of Capricorn?

2. Would any of the countries which are not in the present list, qualify to be a part of OECD countries? Elaborate your thoughts in about ten sentences.

3. Do you think the term *the North* used to describe industrial countries is reasonable? If yes, explain why. If not, describe why this may not be reasonable over long time periods.

4. How many of the OECD countries do you know historically as colonisers? Explain why you call them colonisers. Which countries (their present names) were their colonies?

5. Where are the developing countries of the world located? Does this justify calling them *the South*?

6. You have seen the distribution of various energy sources on a political map of the world in Section 4.8. Would you say that the industrial countries are, in general, rich in energy sources? If not, what drives their industry?

Appendix C

Political Map of the World

You may make as many copies of the map given overleaf as you need for several activities in the booklet.

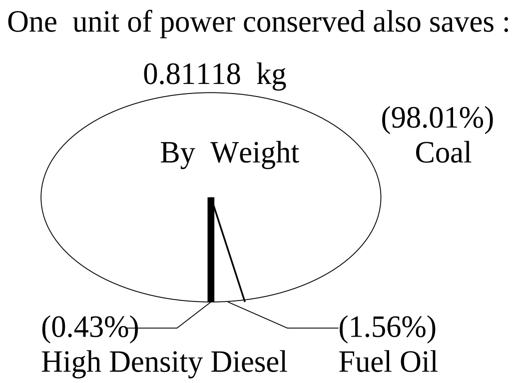
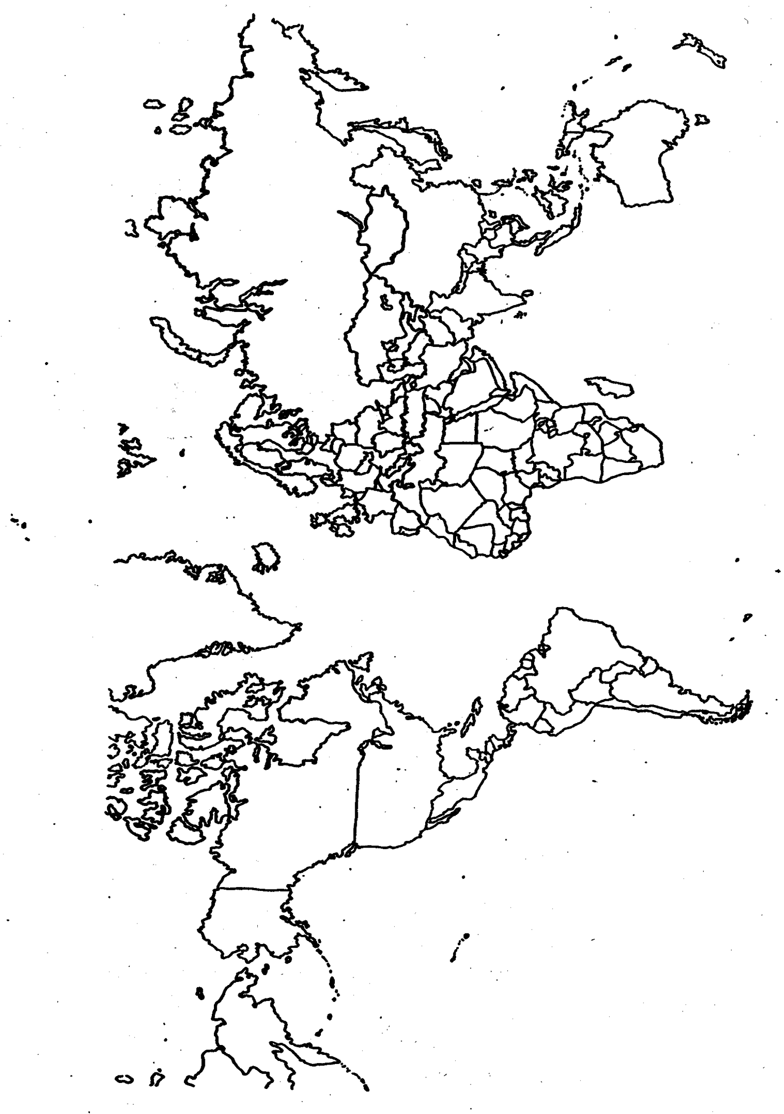


Figure C.1: **Political map of the World**



Appendix D

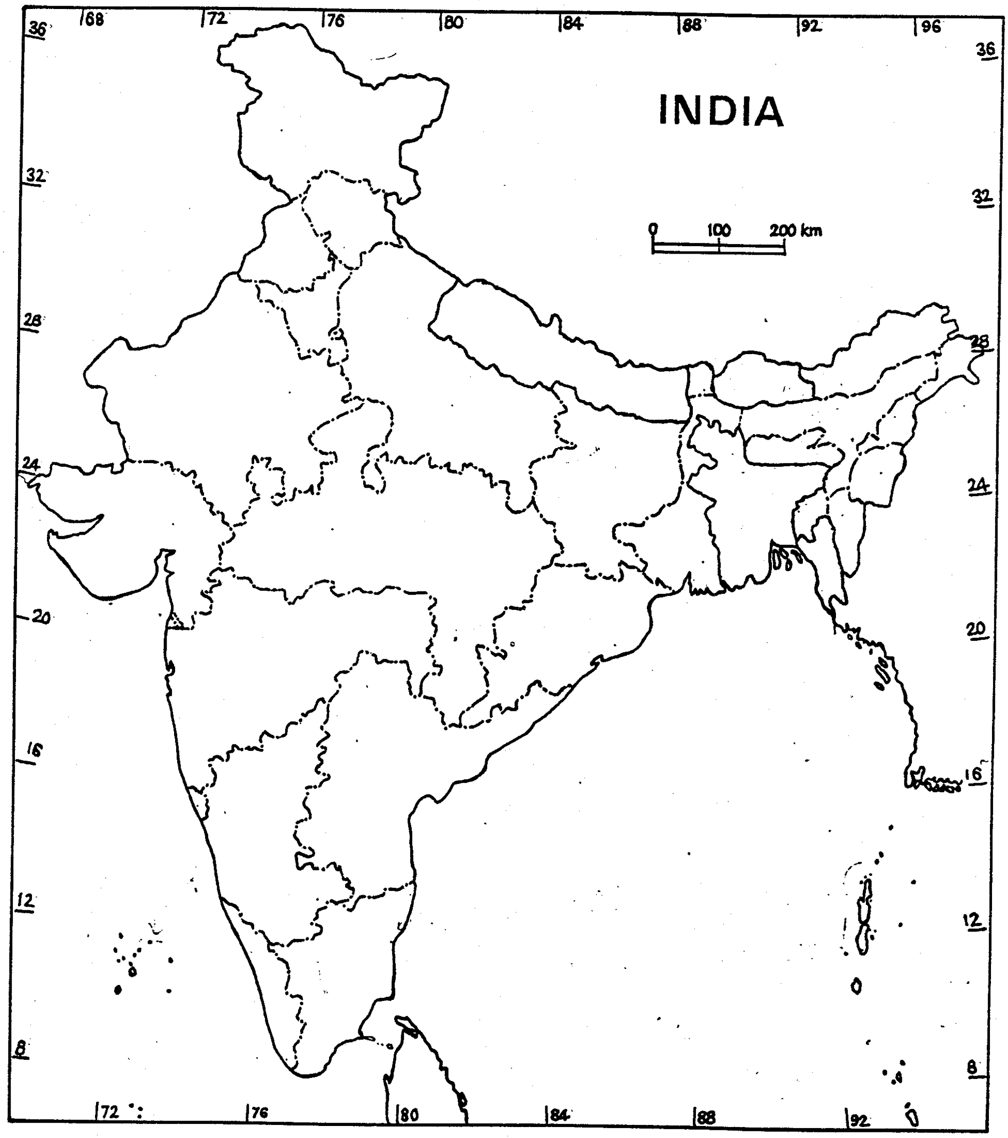
Map of India

You may make as many copies of the map given overleaf as you need for the activities in the booklet.

> "Though they had eyes to see, they saw to no avail; they had ears, but understood not. But like shapes in dreams, through–out their time, without purpose they wrought all things in confusion. They lacked knowledge of houses turned to face the sun, dwelling beneath the ground like swarming ants in sunless caves."

The Greek playwright Aeschylus (524? to 456 B. C.)

Figure D.1: **Political map of India**



Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research
V. N. Purav Marg, Mankhurd,
Mumbai - 400 088.