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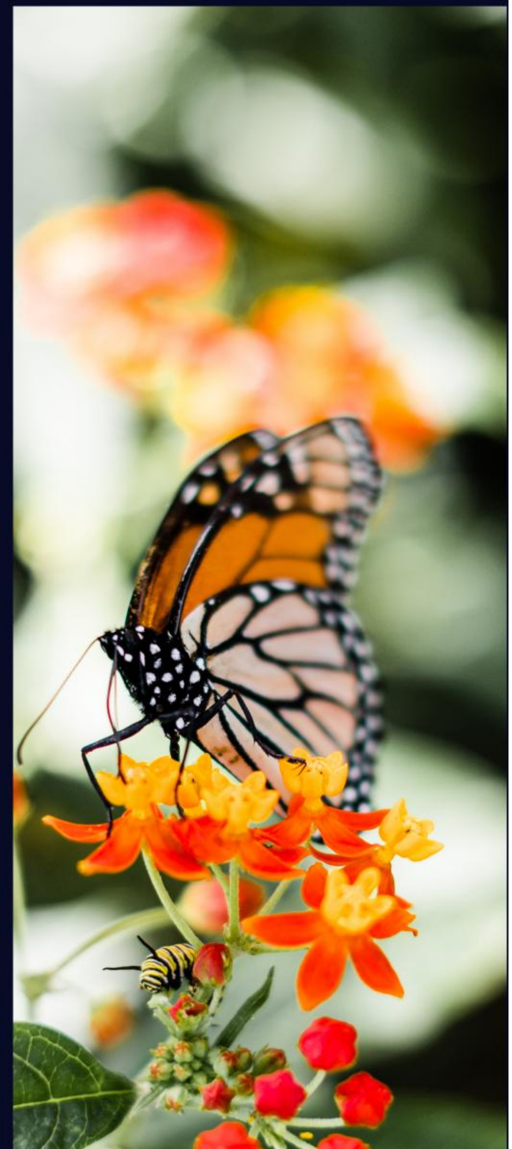

Text Book of
Biodiversity and Bioproductivity

Dr. Mandaloju Venkateshwarlu

Bhumi Publishing

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Dr. Mandaloju Venkateshwarlu

M.Sc., Ph.D., (Botany) M.Sc (Bio-Tech), FSAB, FHAS, SFS, (L.L.B)

Department of Botany,

Kakatiya University, Warangal Urban, Telangana, India

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PREFACE

The book is written in simple language so that the students can easily grasp the matter. Some important terms has been incorporated. So that the students may search the useful related for competitive examinations. In the recent years included in the syllabus of almost all Indian Universities in various subjects of Biology or Life Sciences as an independent evergreen subject. Exponential growth in many areas of basic fundamentals made it necessary in some cases to write several chapters on the same topic which was covered in a single chapter in the earlier book. Similarly, in the present volume, separate new chapters have been written on topics which in the earlier title either did not figure at all or were each covered very briefly as a part of a chapter. In the present book, for instance in separate chapters have been written on new topics. The students of Biology at the post graduate (P.G.) under graduate (U.G.) levels need the recent Global changes and developments. This book will help them to understand the coneptes very easily.

Several of my students in the laboratory helped me either in writing some of the chapters or in preparing the list of references and appendix given at the end of this volume. There may also be errors and omissions of technical nature, since in a vast and fast expanding subject like Botany Biotechnology; one cannot claim to have known everything, despite his best efforts.

I am thankful to Department Head, BOS, Staff and Research Scholars (Botany) my family members, inspiration and cooperation my wife and children's (M. Hamsini) Teachers, Friends, Students and Well-Wishers (Dursheti Sai Charan, M.B.A., Certified Microsoft Office and Windows Specialist). I hope that this book will be useful to students in Life Sciences.

- ***Dr. Mandaloju Venkateshwarlu***

Brief Idea of Biodiversity and Bio Productivity

Generally, there is an increase in biodiversity from the poles to the tropics. Thus localities at lower latitudes have more species than localities at higher latitudes. This is often referred to as the latitudinal gradient in species diversity. Several ecological factors may contribute to the gradient, but the ultimate factor behind many of them is the greater mean temperature at the equator compared to that of the poles. Biodiversity declines from the equator to the poles, some studies claim that this characteristic is unverified in aquatic ecosystems, especially in marine ecosystems. In 2016, an alternative hypothesis ("the fractal biodiversity") was proposed to explain the biodiversity latitudinal gradient. In this study, the species pool size and the fractal nature of ecosystems were combined to clarify some general patterns of this gradient. This hypothesis considers temperature, moisture, and net primary production (NPP) as the main variables of an ecosystem niche and as the axis of the ecological hyper volume. In this way, it is possible to build fractal hyper volumes, whose fractal dimension rises to three moving towards the equator. A biodiversity hotspot is a region with a high level of endemic species that have experienced great habitat loss. The term hotspot was introduced in 1988 by Norman Myers. While hotspots are spread all over the world, the majorities are forest areas and most are located in the tropics.

Brazil's Atlantic Forest is considered one such hotspot, containing roughly 20,000 plant species, 1,350 vertebrates and millions of insects, about half of which occur nowhere else. The island of Madagascar and India are also particularly notable. Colombia is characterized by high biodiversity, with the highest rate of species by area unit worldwide and it has the largest number of endemics (species that are not found naturally anywhere else) of any country. About 10% of the species of the Earth can be found in Colombia, including over 1,900 species of bird, more than in Europe and North America combined, Colombia has 10% of the world's mammal's species, 14% of the amphibian species and 18% of the bird species of the world. Madagascar dry deciduous forests and lowland rainforests possess a high ratio of endemism. Since the island separated from mainland Africa 66 million years ago, many species and ecosystems have evolved independently. Indonesia's 17,000 islands cover 735,355 square miles (1,904,560 km^2) and contain 10% of the world's flowering plants, 12% of mammals and 17% of reptiles, amphibians and birds—along with nearly 240 million people. Many regions of high biodiversity and/or endemism arise from specialized habitats which require unusual adaptations, for example, alpine environments in high mountains, or Northern European peat bogs. Accurately measuring differences in biodiversity can be difficult. Selection bias amongst researchers may contribute to biased empirical research for modern estimates of biodiversity.

Biodiversity is not evenly distributed; rather it varies greatly across the globe as well as within regions. Among other factors, the diversity of all living things (biota) depends on temperature, precipitation, altitude, soils, geography and the presence of other species. Diversity consistently measures higher in the tropics and in other localized regions such as the Cape Floristic Region and lower in Polar Regions generally. Rain forests that have had wet climates for a long time, such as Yasuní National Park in Ecuador, have particularly high biodiversity.

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1 Biodiversity

This universe is the creation of the supreme power meant for the benefit of all His creations. Individual species must, therefore, learn to enjoy its benefits by forming a part of the system in close relation with other species. Let not only one species encroach upon the other's rights. Ishopanishad Native biadiversities a source of pride for each country, composing as it does a shining part of the national heritage. Our National Food Security depends on our ability to conserve all out biological wealth (Dr. M. S. Swaminathan). Variation is the law of nature. It occurs everywhere and every moment. The variations take place at micro levels at short space and small time period, but these become apparent only over a large space and big a time gap. The variations may be linear or cyclic. The variety and variability of organisms and ecosystems is referred to as biological diversity or biodiversity. Similarly, the biological variations initiate at the micro level (bio-molecular level or genes) and become apparent at species and ecosystem level. The biological variations in nature over time and space form the basis of evolutionary processes. Thus, biodiversity is the degree of variety in nature and not nature itself. Similarly, the biological diversity is not the same as biological resource although mutually, they form part of each other. The conservation of biological diversity is distinct but related to biological resources. It is difficult to discretely distinguish the value of biodiversity as a distinct characteristic of biological resources (IUCN *et al.,* 1990).

Biological diversity means the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. Biodiversity provides the basic biotic resource that sustains the human race. This includes diversity within species, between species and of ecosystems. Biodiversity is the most significant national asset and constitutes an enduring resource for supporting the continued existence of human societies. Biodiversity is hot merely a natural resources; it is an embodiment of cultural diversity and the diverse knowledge traditions of different communities across the world. It includes diversity of forms, right from the molecular unit to the individual organism and then on to the population, community and ecosystem and biospheric levels.

The World Commission on Environment and Development (WCED) constituted by the General Assembly of the United Nations published its report in 1987 which provided a major boost and endorsement to the need for conserving the worlds rich biodiversity, particularly that of the tropical areas. Despite conflicting views among nations, a broad consensus was reached after bitter negotiations, and 170 countries signed the Biodiversity Convention, which is now ratified by 104 countries (42 Articles were adopted). One of the prerequisite tasks as expressed by Article 7 of the Convention is the identification and monitoring the components of biological diversity. Article 12 calls for Research and Training and suggest programmes for identification, conservation and sustainable use of biological diversity.

The term biodiversity includes three different aspects, which are closely related to each other. Following are the types of biodiversity:

Genetic Diversity

It refers to the variation of genes within the species. This constitutes distinct population of the same species or genetic variation within population or varieties within a species.

Species Diversity

It refers to the variety of species within a region. Such diversity could be measured on the basis of number of species in a region.

Ecosystem Diversity

In an ecosystem, there may exist different landforms, each of which supports different and specific vegetation. Ecosystem diversity is difficult to measure since the boundaries of the communities, which constitute the various sub ecosystems are elusive. Ecosystem diversity could best be understood if one studies the communities in various ecological niches within the given ecosystem; each community Is associated with definite species complexes. These complexes are related to composition and structure of biodiversity.

Agro-Biodiversity

The agricultural biological diversity more commonly referred to as the agro-biodiversity has been fast emerging as a strong, evolutionary divergent line from the biodiversity, which deals with the life forms at large. It has been specifically recognized to differentiate between concern for ecosystems versus' agro-ecosystems, wild forest flora and fauna versus agriculture related plants, reptiles, insects, avian and microbes; *in situ* conservation of wild forms versus on farm conservation of landgraves and traditional/primitive cultivars or *ex situ* conservation of plant genetic resources, etc. Agro-biodiversity in a traditional farming system is as follows (adopted from Altieri, 1991 and UNDP, 1995).

- Rich in plant and animal species
- A wide diversity of niches in the local environment utilized
- Reuse of organic residues, consuming biomass enabled

- Ecosystem functions, such as pest, weed and disease management enhanced.
- Locally available resources consumed to an advantage.
- Reduction of risk and optimization of resources use.
- Associated with farmers' time tested local knowledge about resources.

Levels of Biodiversity

Global Level

Table 1.1: Estimated number of Species worldwide

Taxonomic Group	No. of Species
Bacteria	3600
Blue green Algae	1700
Fungi	46983
Bryophytes	17000
Gymnosperms	750
Angiosperms	250000
Insects	750000
Sponges	5000
Crustaceans	9000
Molluscs	38000
Star fishes	50000
Fishes	6100
Amphibians	19056
Reptiles	6300
Birds	9036
Mammals	4008

It is estimated that there exists 5-30 million species of living forms on our earth and of these, only 1.5 million have been identified and include 3,00,000 species of green plants and fungi, 8,00,000 species of insects, 40,000 species of vertebrates and 3,60,000 species of microorganisms. Recently it has been estimated that the number of insects alone may be as high as 10 million, but many believe it to be around 5 million. The tropical forests are regarded as the riches in biodiversity. According to the opinion of the scientists more than half of the species on the earth live in moist tropical forests, which is only 7% of the total land surface. Insects (80%) and primates (90%) make up most of the species.

The species diversity in tropics is high as:

1. In tropics; .as Reconditions for evolution were optimum and for extinction fewer. In tropics, species diversity was conserved over geological time. Due to low rates of extinction prevailing there; and
2. Biological diversity is the result of interaction between climate, organisms, topography, parent soil materials, time and heredity.

However, these explanations need experimental observations and confirmation.

Country Level

India is located in south Asia, between latitudes 6° and 38° N and longitudes 69° and 97° E. The Indian landmass extending over a total geographical area of about 3029 million hectares is bounded by Himalayas in the north, the Bay of Bengal in the east the Arabian Sea in the west, and Indian Ocean in the South. The Wide varieties in physical features and climatic situation have resulted in a diversity of ecological habitats. This richness in biodiversity is due to immense variety of climatic and altitudinal conditions coupled with varied ecological habitats. The Indian region having a vast geographical area is quite rich in biodiversity with a sizable percentage of endemic flora and fauna. These vary from the humid tropical Western Ghats to the hot desert of Rajasthan, from the cold desert of Ladakh and the icy mountain of Himalayas to the warm costs of peninsular India.

In India, about 1,15,000 species of plants and animals have been identified and described. For example, the following crops arose in the country and spread throughout the world: rice, sugarcane, asiatic vignas, jute, mango, citrus, banana, several species of millets, several cucurbits, some ornamental orchids, several medicinal and aromatics. Infact, the country has been recognized as one of the world's top 12 megadiversity nations. This region is also a secondary centre of diversity for grain amaranthus, maize, red pepper, soybean, potatoes and rubber plant.

In flora the country, can boast of 45,000 species, which accounts for 15 per cent of the known world plants. Of the 15,000 species of flowering plants, 35 per cent are endemic and located in. 26 endemic centres. Among the monocotyledons, out of 588 genera occurring in the country, 22 are strictly endemic. The North Eastern region boasts of being unique treasure house of orchids in India. The important Indian orchids are *Paphiopedilum fairieyanwn, Cymbidium aloifliurn, Aerides crispum,* etc.

Table 1.2: Number of recorded biota in India

Taxon		No. of species
Flora	Bacteria	850
	Algae	2500
	Fungi	23000
	Lichens	1600
	Bryophyta	2700
	Pteridophyta	1022
	Gymnosperms	64
	Angiosperms	17000
	TOTAL	**48736**
Fauna	Protozoans	2577
	Porifera	519
	Cnidaria	237
	Ctenophore	10
	Platyhelminthes	122
	Nematoda	2350
	Rotifera	310
	Kinoryncha	10
	Gastrotricha	88
	Acanthocephala	110
	Sipuncula	38
	Mollusca	5042
	Echiura	33
	Annelida	1093
	Onychopora	1
	Arthropoda	57525
	Phoronida	3
	Bryozoa	170
	Entoprocta	10
	Brachiopoda	3
	Chaetognatha	30
	Echinodermata	765
	Hemichordata	12
	Protochordata	116
	Fishes	2546
	Amphibians	204
	Reptiles	428
	Birds	1228
	Mammals	372
TOTAL	**126188**	

Table 1.3: Endemic plant and animal species in India

Group		No. of Species	
Plants		Pteridophyta	200
		Angiosperms	4950
Animals	Protozoa	Parasitic	500
		Free living	90
		Lepidoptera	9
	Mollusca	Land & Fresh water	967
	Pisces	Freshwater	64
		Marine	14
		Amphibia	123
		Reptellia	182
		Aves	60
	Mammalia	44	

India is very rich in faunal wealth and has nearly 75,000 animal species, about 80 per cent of which are insects. The distribution of major animal groups is shown in the Table 1.4. In animals, the rate of endemism in reptiles is 33% and in amphibians 62%. Further there is wide diversity in domestic animals, such as buffalo, goat, sheep, pig, poultry, horses, camels and yaks. Domesticated animals too have come from the same cradles of civilization as the major crops.

Table 1.4: Biodiversity in animal species

Group	Number of Species		Percentage of Endemism	World percentage
	World	India		
Mammals	4231	372	8	8.79
Birds	12450	1200	4	9.63
Reptiles	6300	435	33	6.90
Amphibians	4184	181	62	4.32
Fishes	23000	2000		8.69
Insects	800000	60000		7.50
molluscs	100000	5000		0.50

There are no clear estimates about the marine biota though the coastline is 7,000 km long with a shelf zone of 4,52,460 sq km and extended economic zone of 20,13,410 sq km. There is an abundance of seaweeds, fish, crustaceans, molluscs, corals, reptiles and mammals. Information regarding other flora and fauna are patchy. Hundreds of new species may be present in the country awaiting discovery. The Western Ghats in Peninsular India, which extend in the southern states, are a treasure house of species diversity and has about 5,000 species. It is estimated that almost one-third of the animal varieties found in India have taken refuge in Western Ghats of Kerala alone.

The Indian Gene Centre is among the twelve mega-diversity regions of the world. More than 20 crop species were domesticated here. It is known to have more than 49,000 species of plants 18,000 species of higher plants, including major and minor crop (166) and their wild relatives (326). Around 1,000 wild edible plant species are widely exploited by native tribes. These include 145 species of roots and tubers, 521 of leafy vegetables/greens, 101 of buds and flowers, 647 of fruits and 118 of seeds and nuts. In addition, nearly 9,500 plant species of ethno botanical uses have been reported from the country of which around 7,500 are the ethno-medicinal importance and 3,900 are multipurpose, edible species.

Table 1.5: Endangered/ Potentially endangered wild useful taxa of Askot wildlife Sanctuary of Kumaun

Taxa	Local name	Elevation range(m)	Uses
Aconitum heterophylurh	Atis	3500-4500	M
Angelica glauca	Chilpi/Gandraini	3000-4000	M, Ed
Ephedra gerardiana	Somwalli	3000-4500	M
Megacdrpaea polyandra	Rukhi	3300-4200	M, Ed
Mahonla borealis	Bhains/Kirmor	1800-2500	M, Ed, Fu
Pleurospermum angelicoides	Chorak	2000-3000	M, Ed
Quercus lanuginose	Riank	1500-2200	Fd, Fu,Hb
Rheum austral	Dolu	3000-4000	M
Rhododendron anthopogon	Poksin	3000-4000	M, Fu
Taxusbaccata	Huner	2200-3300	M, Fu,Hb
Thalictrum pauciflorum	Mameri	3000-4500	M

(M-Medicinal; Ed-Edible; Fd-Fodder; Fu-Fuel; Hb-House building; Ct-Cultivated tools; Re-Religious)

Wild Plant Wealth

More than 75 per cent of Indian diversity (in the number of species in genera such as *Dendrobium, Bulbophyllum, Liparis, Coelogyne, Paphiopedilum, Vitis, Citrus, Musa, Rhododendron, Hedychium, Elaeacarpus,* and *Elaeagnus* occurs in this region. Over 30 species of legumes and 45 of grasses mainly occur in the temperate belt of the northeast Himalayan region. The legume flora is represented by species of *Astragalus, Caragana, Medicago, Melilotus, Parochetus, Trifolium, Trigonella* and *Vicia,* Among grasses, a large diversity is noticed in genera such as *Agrostis, Alopecurus, Bromus, Calamogrostis, Dactylis, Festuca,* *Glycerin, Loliurru MueNenbergia, Phleum, Poa, Stipa* and *Trisetum.* Local inhabitants gather a wide range of plants -from wild habitats, which provide edible tubers, green leafy vegetables, edible fruits and nuts etc. The more promising of these have been domesticated and/or protected under homestead management.

Ecosystem Diversity in India

These ecosystems harbour and sustain the immense biodiversity. India is one of the 12 megabiodiversity centres in the world. This attributed to the immense variety in physiography and climatic situations resulting in diversity of ecological habitats ranging from tropical subtropical, temperate alpine to desert. (1) Desert, (2) Forests, (3) Grasslands. (4) Wetlands and (5) Mangroves.

Species Diversity

Biogeographically, India is situated at the tri-junction of three realms namely Afro-tropical, Indo Malayan and Paleoarctic realms, and therefore has characteristic element form s in each of them. This assemblage of three distinct realms makes the country rich and unique in biological diversity. Based on the available data, India ranks tenth in the world and fourth in Asia in plant diversity and ranks tenth in the world and fourth in Asia in plant diversity ad ranks tenth in the number of mammalian species and eleventh in the number of endemic species of higher vertebrates in the world.

Status of Survey

At present, 1.75 million species have been recorded so far in the world (Global Biodiversity Assessment, 1995). India's contribution to this record stands at 7% Surveys conducted so far have inventoried over 49,000 species of plants and 81,000 species of animals. As until now, only 70% of the area has been surveyed, it is estimated that the flora and fauna already identified are only a part of what actually occur in India. The list is being constantly added to especially in the case of lower plants and invertebrate animals. Survey and inventorisation of India's biodiversity is still far from competing, especially for the lower groups of plants and invertebrate animals.

As noted earlier 49,000 species of flowering and non-flowering plants representing about 12% of the recorded world's flora, have already been identified. Significant diversity has been recorded in pteridophytes with 1022 species and Orchidaceae with 1082 species. Comparative statement of recorded number of plants species in India and World is given in table (1.1) to (1.5).

2 Uses of Biodiversity

Smith the greatest of classical economists stated that the origin of all wealth came from the bosom of earth, implying the existence of great bondage between Economics and the Earth's resources, especially biodiversity. The value placed on biodiversity depends on whether it is a private or social one. Private value is given by the 'price' of the resource itself, while social value refers to the value of the resource to society. The social value of biodiversity in reality refers to the manner, in which bioresources are used, or: abused, but not actually estimated in terms of their 'worth' to society. Hence the social value of biodiversity tends to vary between countries and between cultures. Societal status, social preferences, degree of technological advances and the distribution of income and assets are some of the factors largely responsible for the differential perception of value of bioresources between countries and cultures.

Although for certain resources the market prices will also reflect social value, for bioresources the private value differs from the social (Perrings 1997) and the former tend to be very poor approximations of social value. The components of biodiversity are a part of the wealth of society and their allocation between competing uses largely depends on their relative private value. Private value of biodiversity components needs to be understood in order to ascertain the driving forces behind biodiversity loss, while their social value has also to be understood in order to know how much biodiversity should be conserved (Perrings 1997).

There is also a debate on whether values are to be considered 'ethical judgments or equivalence measures' (UNEP 1995), i.e., whether values are statements of principle or a reflection of social opportunity costs (Turner and Eearce 1993; UNEP 1995). Ethical judgments influence people's preferences and therefore can be 'translated into a willingness to commit resources to biodiversity conservation' (Perrings 1997). Equivalence measures of value that are needed to fix the desirable level of conservation are the 'opportunities foregone in committing resources to conservation' (Perrings 1997). Equivalence measures of value in reality are not blind to ethical judgements (UNEP 1995) and *vice versa.*

Individuals may place the same value on biodiversity but commit very different resources to it due to differences in their monetary endowments. For example, a developed and a developing country may place the same value on biodiversity but commit very different amounts to, say/its conservation because their monetary backgrounds differ. In other words, valuation of biodiversity reflects the relative importance of both valuation of biodiversity in a society and the latter's ability to pay for it. A rich country willing to pay more for biodiversity than a poor country does not signify that the components of biodiversity in the former are more valuable than the components of biodiversity in the poor country. In other words, the most important point here is the distribution of income and assets (Perrings 1997).

Uses of Plants

Species of plants provide an array of products used by people worldwide. Certain plants can be exploited directly from the .wild, while others sustain humanity through cultivation. In spite of vast overall development, plant biodiversity as a global resource largely remains poorly understood, underexploited and poorly documented. Knowledge of plant use from indigenous people has not been translated into wider use largely because of poor documentation of ethnic information. However, plants have been a major source, of food, medicine, horticultural and ornamental plants, timber, fibre, dyes and other chemicals, fuel and renewable energy, and a host of other products used in industry and commerce. A general outline of the major uses of plants is provided below.

Food

The most important contribution of plants to humanity is food: In the early years of man's evolution, plants were consumed raw and obtained from the wild; gathering Food from the wild continues even today in tribal communities throughout the world. However, with the evolution of civilisation, man began to domesticate plants for food. Of the about 250,000 species of flowering plants, 75,000 species are edible but to date only about 3000 are regarded as a source of food. Of these, around 200 plant species have been domesticated with 15-20 constituting crops of major economic value. Species belonging to Poaceae, Papilionaceae, Brassicaceae, Rosaceae, Apiaceae, Solanaceae, Lamiaceae, Chenopodiaceae, Araceae, Cucurbitaceae and Asteraceae are the- -major sources of food.

The very high probability of global climatic changes is expected to cause large-scale shifts in natural vegetation and agricultural crops. Hence there is urgent need to protect genetic resources of food plants to maintain crop productivity in different climatic conditions. Wild species related to crop plants often provide this 'insurance value', as already indicated in Chapter 4. Heywood (1992) has suggested that there are several species of useful plants in the tropics alone whose uses could be extended from emergency sustenance in isolated locations or disaster areas to fully exploitable alternative sources of food. Future prospects are limitless and unforeseeable.

Fodder and Forage

Many species of plants are used as fodder. They are either used directly from the wild, as in pastures and rangelands, or domesticated. Grasses and legumes are the most important fodder sources.

Timber

Wood, the source of timber, is one of the most utilised plant commercial commodities throughout the world. Although predominantly harvested from the wild, monoculture plantations under agro-and social-forestry programmes are increasingly being raised as a source of timber. Wild sources of timber, especially from hardwoods, are predominantly tropical and, in fact, account for a very significant proportion of export earnings for developing countries in the tropics. The USA, some European countries and former USSR provinces account for the major supply of softwoods. Malaysia, Myanmar, Indonesia, Papua New Guinea and Gabon are the most important tropical countries involved in timber trade. Wood is exported as logs,, sawn wood or plywood. It is difficult to assess the extent to which timber either for domestic consumption or for export is derived from plantations. Industrial timber plantations of temperate countries predominantly consist of coniferous species.

Ghana has 674 tree species of great timber potential but timber is exploited from only 60 species in the past. Peninsular Malaysia has about 3000 tree species, of which over 400 have been a source of good timber for national and international markets. Because of continual exploitation and lack of adequate replantation, most timber tree species of tropical countries are now threatened; habitat loss, forest fragmentation, improper and inadequate management etc. have also contributed to this threat. More than 80 tree species of timber value are already listed as endangered the world over.

Rattans and Canes

Rattans and canes constitute the most important resources exported from tropical countries. Most of the 600 or so species, all belonging to Arecaceae (palms), are native to South and Southeast Asia and the vast majority are endemics. The Philippines, China, Indonesia, India, Sri Lanka and Thailand .are the most important rattan exporting countries. Rattans and canes are used for cane furniture, mats, baskets, fish traps, dyes, medicines etc.

Rattans and canes are obtained almost exclusively from wild sources, although 10% of the supply comes from plantations in Central and South Kalimantan. They are mainly obtained from species of Calamus (15 species of this genus are more important sources).

Medicinal Plants

Plants are very important in health care. In less developed/ developing countries, 80% of the people still rely only on traditional medicines obtained from local plants and 85% of traditional medicine involves the use of plant extracts (Farnsworth 1988). Further, since adequate hospital facilities and allopathic doctors are absent in much of the tropics, any destruction of tropical forests would concomitantly destroy the primary healthcare network involving local plants and traditional 'doctors' (Balick 1990). Some 200 chemicals extracted in pure form from circa 90 plant species are used in medicine throughout the world, i.e., about half of the world's medicinal compounds are still derived or obtained from plant sources (Hamann 1991). Many of these chemicals cannot be synthesised. Therefore, medicinal plants are of great significance to both developed and developing countries.

At present only a very small percentage of the world's plants contribute on a global scale to health care. There is clearly a great range of higher plants from which to draw and there is also a great repository of traditional knowledge in the various cultures/societies of people using medicinal plants. WHO has listed over 21,000 plant species worldwide which are reportedly of medicinal value Heywood (1991a) estimated some 25,000 species of medicinal plants. More than 2500 species of plants are used in the Ayurveda, Siddha, Unani and other traditional health care systems.

Natural plant diversity might be increasingly valued for the blueprints' it provides for new synthetic drugs, in spite of an increasing technology to design and manufacture synthetic drugs. Principle (1991) estimated that the potential annual market value in OECD countries of the species of medicinal plants likely to vanish before the year 2050 is US$60 million. This figure is about 0.15% of the amount spent on plant-based medicines. It represents a benefit foregone rather than an actual loss. It is, however, only a market value and does not include other components of the total economic worth of the drugs, such as the cost to a society deprived of them and the benefits of good health. Therefore, the total economic value could be 5 to 50-fold higher.

Medicinal plants, especially those used in traditional medicine, are still largely harvested from the wild and relatively few cultivated. Cultivation has been attempted only for the last 25 years and a number of medicinal plants have reportedly lost/ become poor in medicinal properties upon cultivation. Yet species such as *Papaver somniferum, Cinchona officinalis, Mentha piperita, Ocimum sanctum, Digitalis purpurea, Gentiana lutea, Valeriana mexicana, Vinca rosea* and others have been effectively domesticated.

Because of constant exploitation, a number of medicinal taxa have become threatened in various parts of the world. Such taxa include spedeso Wioscorea/Ephedra, Solanum, Rauvolfia, Parkia and others.

Ornamentals

Ornamentals are domesticated wild plants and like food plants have a long history. In China, lilies have been cultivated for more than 2000 years and similarly in Rome, roses, violets, anemones, narcissi and lavender have a long history of cultivation. The number of ornamental and decorative plants under cultivation far exceeds the number of food plants. In the UK alone, circa 3000 species are ornamentals.

Ornamentals are important commercially and contribute significantly to international trade in countries such as the Netherlands, the USA and Japan. Both whole plants and cut organs such as flowers and leaves/twigs have 'ornamental value. Among whole plants of importance, the most important are orchids, succulents (cacti and euphorbias), cycads, insectivorous plants, bulbous species etc. Cut flowers of orchids, tulips, lilies, narcissi, violets, roses, anemones etc. are very important. More than 5000 species of orchids and their hybrids were recorded in the trade statistics of CITES during 1983-1989, a figure that must have increased substantially by now. Thailand, Malaysia and India account for major trade in tropical orchids. Although a number of these orchids are artificially propagated in vivo and in vitro, exploitation from natural habitats is still enormous, threatening endangerment of many orchid species. .In Japan, already 70 taxa of orchids have been entered in Red data lists. CITES appendix 1 includes species of Paphiopedilum and Phragmipedium as highly endangered.

The average international trade in cacti per annum is approximately 14 million plants as per CITES statistics, obviously a gross underestimate. One nursery in the Netherlands alone produces over 18 million cacti annually, the USA between 10-50 million, while Mexico exports around 50,000 every year. The most important succulent genera (other than cacti) in terms of commercial value are Aloe, Euphorbia and Pachypodium. Madagascar is among the chief exporters of succulents at around 135,000 plants annually according to CITES—all collected from the wild.

The bulbous plants form the next important group of ornamentals, albeit little information about them was available from CITES. While wild sources still contribute substantially, domesticated Bulbous plants are very important commercially: Galanthus, Cyclamen, Allium, Anemone, Arum, Crocus, Dracunculus, Eranthis, Fritillaria, Hyacinthus, Lilium, Muscari, Narcissus, Pancratium, Scilla, Tulipa and Urginea.

Other Uses

Plants have several other uses but only the most important are mentioned here. A number of species yield fibres of great value for cloth and other industrial purposes. Cotton, linen, jute, sisal, hemp, coconut, etc. are some of the fibres obtained. A number of fibre plants have been domesticated (cotton, linen, jute etc.) but fibres from wild taxa are still widely obtained, especially in tribal and rural areas. Plants offer a good source of fuel, either as wood (firewood) or its transformed product, charcoal. Plant biomass from any source can also be converted into fuel. In fact, plants are very efficient sources of renewable energy. Natural rubber, latex, gums, resins, dyes, essential oils and beverages are some of the other products of commercial value obtained from plants.

Table 2.1: Applications of microbially derived antibiotics

Antibiotics	Applications
Penicillins, Cephalosporins, Rifamycins	Antibacterial
Amphotericin B, Griseofulvin, Nystatin, Hamycin	Antifungal
Abikoviromycin, Kikumycin	Antiviral
Adriamycin, Belomycin	Antitumour
Avermectin, Hygromycin	Anthelmintic
Herbicidin	Herbicide
Milbemycin	Miticide
Tetranectin	Insecticide
Gibberellins	Plant hormone
Monascin	Food pigment
Detoxin	Detoxicant
Azalomycin	Antiprotozoal
Nisin	Food additive
Variginiamycin	Animal growth promoter
Colisan, Patulin	Antispasmodic
Monorden	Tranquillizer
Cyclosporin A, Alanosine	Immunosuppressive
Griseofulvin, Amicomycin	Anti-inflammatory
Depastin, piramycin	Hypertensive
Filipin, Nogalomycin	Anticoagulant

Uses of Microbes

Microbes are useful in many ways. One of their major users is the pharmaceutical industry. Their capacity to ferment various substrates has led to the production of a number of clinically and otherwise important antibiotics (see Table 2.1). Microbes are also good sources of various medicinally important enzymes (streptokinase and asparginase), toxins (botulin), immune modulators (Cyclosporin A), hypolipidaemic (Lovastatin) etc. Vaccines such as BCG, typhoid, hepatitis B, hormones, and alkaloids such as ergot are also derived from some microbes. The ability of micro-organisms, especially transgenically modified ones, to transform steroids and antibiotics has also been successfully exploited by the pharmaceutical industry in recent years. Single cell proteins, microbicides, pesticides, insecticides and fungicides, flavoring agents, alcohol, acetone, butanol, glycerol and organic acids such as citric acid, fumaric, acetic and lactic, are also derived from the activity of microbes.

Several micro-organisms are highly useful in the agricultural industry, either as biofertilizers due to their capacity to fix atmospheric nitrogen or in phosphate solubilisation. Some soil bacteria, such as Pseudomonas putida, enhance plant growth by producing very characteristic plant-growth regulators. Other important roles of micro-organisms include biomining (biologically extracted mineral ores), bioremediation (cleansing the environment through absorption or biotransformation of toxic chemicals), biosorption, biogas production, harnessing solar energy etc. Thus the uses of microbes are highly diverse and can be pithily summarised in this statement: 'Microbes can and will do anything; microbes are smarter, wiser and more energetic than microbiologists, chemists, engineers and others' Naresh Kumar (1998), by quoting Perlman in Biodiplomacy.

3 Valuing Biodiversity

Valuing biodiversity is mandatory even though it is really beyond valuation. At least three important systems of classification of values of biodiversity have been proposed to date whose salient features are summarised in Box 3.1. The first system of classification of biodiversity values breaks the value down into a number of components: use or non-use, direct or indirect use, consumptive or productive use etc. This system looks at biodiversity from the point of view of a practising economist. The most important and recent formulations incorporating these components for calculating the total value of biodiversity are provided in Box 3.1. The component values involved in these formulations are defined and, in some cases briefly explained below:

Box 3.1: Formulations of the components of biodiversity values as per various authors

I. First system of classifications

1. Given (1996); McNeely (1988)
   DV(CUV, PUV) + IV (MUV, OV, EV)
2. Pearce (1990); Pearce and Moran (1994).
   TEV = UV + NV = (DUV + IUV + OV) +(EV + BV)
3. UNEP (1995)
   i. TEV = F [DUV, LUV, OV, QOV (Use Values), BV, EV (Passive or non-use value)]
   ii. TEnV = G [PV (Non-anthropocentric instrumental value), TEV (Anthropocentric value)]
4. Perrings (1997)
   V = F (DUV, IUV, OV, QOV, BV, EV)
5. Ravi and Pushpangadan (1997)
   TEV = DUV (CUV, PUV, NUV) + IUV + OV +QOV + NV (EV, AV)

II. Second system of classification

6. Meffe and Carroll (1994)
   TEV = I_1V(G,S,I, PS) + I_2V

III. Third system of classification

7. Norton (1987)
   TEV = DeV+ I_2V + TrV

1. Total Environmental Value (TEnV):

UNEP (1995) defined this as a function of primary value and total economic value. A team of ecologists and economists working together arrived at a surrogate evaluation of all the environmental goods and services. It amounts to $33 trillion worldwide per year and thus is larger than the global economy of $29 trillion (1997 figures) (Myers 2000). In other words, global natural resources are more valuable than global national products.

2. Primary value (PV):

This may be defined as the value of the system characteristics upon which all ecosystem functions depend (UNEP 1995).Therefore, it represents the prior value of the ecosystem; it is called the primary value because the structured ecosystem produces functions which have secondary value. The secondary value will exist as long as the ecosystem retains its 'health', existence, homeostasis, operation and maintenance. The primary value is also known as 'glue' value since its notion is related to the fact that the system holds everything together and in principle, therefore, has economic value.

3. Total Economic Value (TEV):

Also called Total Value (TV) or simply Value (V). TEV denotes the sum total of all kinds of values attached to .biodiversity minus the primary value. According to UNEP (1995), it is the function of use and non-use values, 'with due consideration of any trade-offs or mutually exclusive uses or functions of the resources/habitat in question'. Care must be taken to avoid simply adding up the resultant, values to obtain TEV. Total Economic Value by itself will underestimate the true value of ecosystems; it has to be considered along with the primary value for which details are priorly provided.

4. Use Value (UV):

This represents the value arising from an actual use made of a given component of biodiversity (MacArthur 1997). It is often a function of Direct and Indirect Use Values. Pearce (1990) and Pearce and Moran (1994) also include Option Value as a third if unction of use value, while UNEP (1995) includes Quasi-option Value also under use value.

5. Direct Use Value (DUV):

Also called Direct Value. MacArfhur (1997) defines this as actual uses, especially in consumption. According to UNEP (1995), it represents the economic values derived from direct use or interaction with a biological resource or resource system. The bioresource makes .a direct contribution to human welfare in the form of either enjoyment or satisfaction. DUV is relatively easily observed and measured, often by assigning market prices. McNeely (1988) considers DUV a function of Consumptive Use Value (GUV) and Productive Use Value (PUV). Ravi and

Pushpangadan (1997) consider DUV as a function of CUV, PUV and Non consumptive Use -value (NUV). Some estimates of direct use values of selected wild resources are shown in Table 3.2.

Table 3.2: Estimates of direct use value of selected wild resources in developing countries (in US $)

Activity/Use	Estimated Value	Source
Preban ivory exports, Africa	$35-45 million/year	Barbier *et al.,*, (1990)
Viewing value of elephants, Kenya	$25 million/year	Brown & Henry (1993)
Tropical forest product exports	$11 billion/year	Barbier *et al.,*, (1994)
Fruit/latex, forest, harvesting, Peru	$6330/ha	Peters *et al.*, (1989)
Sustainable timber harvesting, Peru	$490/ha	Peters *et al.*, (1989)
Pharmaceutical prospecting, Costa Rica	$4.81 million/product	Alyward (1993)
Buffalo range ranching, Zimbabwe	$3.5-4.5/ha	Child (1990)
Wetlands fish & fuel wood, Nigeria	$38-59/ha	Barbier *et al.,*, (1991)
Ecotourism, Costa Rica	$1250/ha	Tobias (1991)
Tourism, Thailand	$385-860,000/year	Dixon (1990)
Genetic value, Cameroon	$7/ha	Ruitenbeek (1989b)
Medicinal plants in Belize	36-166 ($/ha/year)	Balik (1992)
Gross benefits from fruits, herbs, Medicinal plants etc. in India	117-144 ($/ha/year)	Chopra (1993)
BraziCnuts only in Brazil	97 ($ /ha/year)	Mori (1992)
Fuel and fodder in Tamil Nadu, India	80 ($ /ha/year)	Appasamy (1993)

6. Consumptive Use Value (CUV):

This is a type of direct use value and represents the value placed on a biodiversity component that is consumed / enjoyed directly, without passing through a market (Given 1996; Groombridge 1992; McNeely 1988). Recreation may be cited as an example. Ravi and Pushpangadan (1997) give an altogether different definition for CUV Consumption in physical form and include all types of biomass (food, fuel, fruit, fodder, medicine, industrial raw materials such as herbs for pharmaceutical preparations, wood for different uses and microbial products) as examples. Many of these in fact do pass through a market while some do not. Consumptive use values seldom appear in the GNP of countries but are nonetheless very important. Fuel wood is a consumptive value of great importance in rural areas.

7. Productive Use Value (PUV):

The value given to a component of biodiversity that is commercially harvested or is a source for a commercially harvestable product; such items pass through a market. Examples: minor forest produce, fruits and seeds, latex, timber, pharmaceuticals, medicines, fibres, gums and resins, wild relatives of cultivated plants. Table 3.3 provides some information on the value of productivity contributions of wild relatives of crop plants. The values of such items are usually estimated at the production end (landed value, harvested value, farm gate value etc.). PUV is included in national economic statements and budgets.

Table 3.3: Examples of productivity contributions of wild relatives of crops (after UNEP 1995)

Crop	Found in	Effect on Production
Wheat	Turkey	Genetic resistance to disease; valued at US $50 million/year
Rice	India	Wild strain proved resistant to the grassy stunt virus
Barley	Ethiopia	Protects California's US $160 million/year crop from yellow dwarf virus
Hops	N. Europe	Added US $15 million to British brewing industry in 1981 by lessening bitterness
Beans	Mexico	Genes from the wild Mexican bean used to improve resistance to the Mexican bean weevil which priorly destroyed as much as 25% of stored beans in Africa and 15% in South America
Grapes	Texas	Texas rootstock used to revitalise the European wine industry in the 1860s after a louse infection

8. Indirect Use Value (IUV):

MacArthur (1997) defined this as 'benefits arising from an ecosystem function'. It represents the 'economic value derived from the role of resources and systems in supporting for protecting activities whose outputs have direct value in production or consumption' (MacArthur 1997; UNEP 1995). Indirect contributions of biodiversity to human welfare are said to have this value. As examples for indirect contributions of biodiversity the following may be mentioned: biogeochemical cycles, photosynthesis, climate regulation, pollutant degradation, prevention of soil loss. Table 3.4 give an idea of the indirect use value of biodiversity.

Table 3.4: Estimates f the indirect use value of ecological functions (US $) (after UNEP 1995)

Resources/ Function	Estimated Value
Cameroon	
Watershed protection of fisheries	$ 54/ha
Control of flooding by forests	$ 23/ha
Soil fertility maintenance by forests	$ 8/ha
Philippines	
Watershed protection of marine tourism	$ 13.9-19.2 million
Watershed protection of fisheries	$ 6.2-8.1 million
USA	
Water yield augmentation of managed forests	$ 232-388/acre
Brazil	
Carbon storage by forests	$ 1300/ha/year
Indonesia	
Support by mangroves of agriculture, fishing and cottage industries	$ 536 million
Sweden	
Nitrogen reduction by restored wetlands	$ 18.7/kg N-reduction

9. Non-Consumptive Use Value:

This refers to the value which the components/systems of biodiversity possess in terms of functions or services offered. Some consider this a subcategory of IUV (Given 1996; McNeely 1988), while others. (Ravi and Pushpangadan 1997) -treat it as a category of DUV.

10. Non-Use Value (NV):

Defined as the 'value relating to safeguarding the existence of assets, even though not related to their actual use in a foreseeable period' (MacArthur 1997). NV is also referred to as Passive Use Value, referring to the value of a biodiversity resource 'in production or consumption to someone/ thing other than the user'. Such a value exists 'where individuals who do not intend to make use of such resources would nevertheless feel a "loss" if they were to disappear' (Brown 1990; Randall 1991). In view of this, people may like to conserve such biodiversity resources in their own right.

11. Option Value (OV):

Defined as 'willingness to pay to safeguard an asset for the option of using it in future' (MacArthur 1997). UNEP (1995) defined OV as follows: 'The potential value of the resource for future (direct and indirect) use'. The wild relatives of cultivated plants that are yet to be exploited may be cited as examples of biodiversity components possessing OV.

12. Quasi-Option Value (QOV):

According to UNEP (1995), QOV represents 'the value of the future information made available through the preservation of a resource' (also see Arrow and Fisher 1974). It should be mentioned that the distinction between option and quasi-option values is not always maintained.

13. Existence Value (EV):

Defined as the value 'deriving from the existence of a particular asset' (MacArthur 1997). UNEP (1995) defines EV as the value of knowing that a particular species, habitat or ecosystem does and will continue to exist. It is independent of any use that the value may make of the resource' EV notes the benefits derived by any one individual from the mere knowledge that the bioresource exists (see Pearce and Moran 1994). People, who have donated money to a conservation organisation without expecting anything in return other than the satisfaction of knowing they have contributed something to the cause of biodiversity, may be said to have realised the existence value of biodiversity. Existence values of biodiversity generally generate sympathy and concern among people.

14. Bequest Value (BV):

This is the 'value of knowing that others may benefit from the existence of an asset in future'(MacArthur 1997). According to UNEP (1995) it is a 'value defined by willingness to pay, to ensure that people's offspring of future generations inherit a particular environmental asset'. This value may thus be considered as the value of keeping a resource intact for one's heirs (Krutilla 1967). Some people, for example Aldred (1994), view B V as merely one of a number of types of Existence Value, and not warranting a separate category. The recognition of a number of different categories of values by economists has created problems for lay biologists (who lack sufficient knowledge of economics) in understanding the real concept behind each of these subcategories of values. There is lack of clear-cut demarcation between at least some of these categories, and definitions and understandings overlap. The different classifications proposed by economists compound' these problems, as different subcategories find different positions in different classifications. Lay biologists expect a simpler classification, which they can follow and practise without much difficulty. It is from this standpoint that the second classification system proposed by Meffe and Carroll (1994) captures our attention.

Meffe and Carroll (1994) detailed a second system of classification of values of Biodiversity Value, as per this system, is classified into Instrumental (I1V) and Inherent Values. The first is the value that something (in biodiversity has as a means to another's ends. In other words the components of biodiversity that art instrumental (i.e., absolutely necessary) in providing the material basis of human life come under this category. At one level these components maintain the biosphere as a functioning system and at another provide the basic materials for all utilitarian needs. Instrumental value depending on the manner in which it constitutes the means to another's ends, can be divided into four categories of values. Goods, Services, Information and Psycho spiritual. The components of biodiversity that provide the basis for food, forage, fuel, medicine, useful chemicals, fibre, ornamentals etc. (Hawkes 1987) come under goods. Pollination, dispersal of fruits and seeds, nutrient recycling, nitrogen fixation, biogeochemical cycles, role in maintaining stable environment including soil stability, water purification, flood control, coastline stabilisation, waste treatment, disease; regulation, maintenance of air quality etc., are some of the services rendered by biodiversity. Primary productivity through carbon sequestration is one of the most important services of plant biodiversity.

The net primary productivity globally amounts to about 225 billion metric tons of organic matter annually (Ehrlich 1988). Biocontrol of pests/pathogens is another important service rendered by some components of biodiversity. If we accept the Gaia Hypothesis (Lovelock 1988a, b), the earth’s temperature and the ocean's salinity are controlled by biodiversity. The information value of biodiversity is reflected in various aspects of basic sciences, applied biology, genetic engineering etc. It thereby emphasises the scientific value of plants, animals and microbes. The genetic information contained in elements of biodiversity is a very potential economic good and can be exploited for biotechnological applications. As Meadows (1990) states: 'Biodiversity contains the accumulated wisdom of nature and the key to its future. Nature's knowledge is contained in the DNA within living cells. The variety of genetic information is the driving engine of evolution, the immune system for life, the source of adaptability'.

The Psychospiritual Value'is very difficult to define and can only be explained indirectly through examples. Meffe and Carroll (1994) cite aesthetic beauty, religious awe and scientific knowledge as some examples of the psychospiritual value category. The feeling "of 'biophilia', according to Wilson (1984), can be equated to the special wonder, awe, arid mystery in nature that one finds. It is the feeling of preference for Nature's variety instead of monotony (Soule 1985). In other words, psychospiritual value is the realization that an ordinary plant, however ordinary it may be, is as potentially beautiful as any work of craft or art.

The Intrinsic value, as per this second system of classification (Meffe and Carroll 1994), is the value that something (some component of or the entire biodiversity) "has as an end in itself" (Meffe and Carroll, 1994). The intrinsic value of biodiversity, as a whole, is a matter of great controversy; some question its recognition as a separate category. Unlike Instrumental value, intrinsic value cannot be divided into subcategories. .It is also not clearly known whether intrinsic value exists objectively or is objectively conferred. Which aspects of biodiversity could be considered to possess intrinsic value per se is another unresolved problem (Callicott 1986; Elliot 1992). If one values some component of biodiversity for its own sake, irrespective of its role, the intrinsic value of that component would appear to be subjectively conferred. Contrarily, if the value of some component of biodiversity is automatically recognised or felt by an individual, its intrinsic value can be said to exist objectively.

Intrinsic and instrumental values are not mutually exclusive; many components of biodiversity may be valued not only for their utility, but also for themselves. Hence Norton (1991) has argued that by dividing biodiversity values into Instrumental and Intrinsic, one is doing more harm than good to the conservation of biodiversity. According to him, the intrinsic value issue has divided biodiversity dentists into two mutually suspicious fractions: Anthropocentrists and Non-anthropocentrists.

Norton (1987) advocated the thir system of classification of the values of biodiversity. He recognised three kinds of values for Biodiversity: Demand value, Intrinsic value and Transformative value. Demand values occur when a component of biodiversity provides satisfaction for some felt preferences, commonly recognised in terms of Goods, Services and Information. Intrinsic value is defined in the sense already discussed in the second system of classification of values, i.e., a component of biodiversity can have value of and in itself , without reference to its usefulness to humanity. So, intrinsic value cannot be quantified. Transformative value exists where the object of biodiversity provides 'the occasion for examining or altering a felt preference rather than simply satisfying it'. It involves a transformation of, or change in a person's earlier set of felt preferences.

Precautionary Principle

At present, only a relatively small percentage of biodiversity is actively exploited by man and valued. However, there-are other elements of biodiversity that may be very important for the different reasons listed below:

- They may have values unused or unknown at present, but once discovered and exploited, could substantially, enhance the well-being of humankind.
- They may become useful at some future time due to changing circumstances.

These reasons support a precautionary approach to maintenance of all biodiversity. Biodiversity elements with actual (yet unknown) or potential use should not be lost simply because we presently do not know their value. Further, it must be understood that biodiversity elements price lost cannot be recreated even with our best technologies. In addition to future options for humanity, future options for continuation of evolution of biodiversity elements (such as genes, species—and ecosystems) should be borne in mind. The aforesaid are in essence the tenets of the precautionary principle.

Methodologies for Valuation of Biodiversity

Many methods for quantifying the benefits of biodiversity, i.e., for valuation, have been proposed and refined by the growing group of Environmental Economists. Some of these methods are listed in Table 3.5 from which it is evident that the terms used in the different approaches and methodologies vary considerably but do not actually reflect dissent regarding content and coverage. It is not necessary to detail all the methodologies developed so far. Only the most important are described below:

Table 3.5: methods for valuation of biodiversity provided by recent workers
(based in part on MacArthur).

I. Dixon and Sherman (1990)

- **1.** Techniques based on market prices
  - a. Change in productivity approach
  - b. oss of earnings approach
- **2.** Techniques based on surrogate market prices
  - a. Hedonic pricing
    - i. Property value
    - ii. Wage differential
- **3.** Survey-based approaches
  - a. Contingent valuation methods
    - i. Compensating variation
    - ii. Equivalent variation
  - b. Delphi techniques
- **4.** Cost-based approaches
  - a. Opportunity cost of lost benefits
  - b. Alternative cost
  - c. Cost effectiveness
  - d. Expenditure-based approaches
    - i. Preventive expenditure approaches

ii. Mitigation cost approach
iii. Replacement cost approach
iv. Shadow project
v. Relocation cost approach

II. Winpenny (1991)

1. Effect on production approach
2. Prevention expenditure and replacement cost
    a. Prevention expenditure
    b. Replacement cost
3. Human capital
4. Hedonic methods
    a. Property value
    b. Wage differential
5. Travel cost method
6. Contingeny valuation method
    a. WTP
    b. WTA

III. Pearce and Moran (1994)

1. Direct methods
    a. Experimentation (and Research)
    b. Questionnaires
        i. Contingent ranking
        ii. Contingent valuation
2. indirect methods
    a. Hedonic values
        i. Land values
        ii. Wage premia/penalties
    b. Travel costs
    c. Aversive method
3. Contingent market approach
    a. Dose response
    b. Replacement cost

IV. UNEP (1995)

1. Contingent valuation and Ranking

a. Contingent valuation
b. Contingent Ranking

2. Revealed preference method
    a. Travel cost method
    b. Hedonic travel cost method
    c. Random utility method
3. Production function approaches
4. Revealed preference and opportunity cost methods
    a. Change in Productivity
    b. Change in earnings
    c. Defencive or Preventive expenditures
    d. Replacement cost
    e. Substitution or proxy
    f. Shadow roject
    g. Copensation costs
    h. Benefits transfer

Changes in Productivity Method

This is also known as the Production Function method. Changes in the supply of biodiversity resources result in changes in the economic value of their production. This principle underpins the Production Function method. Changes in the supply of resources may occur for several reasons, including habitat changes, loss of biodiversity components etc. For example, soil degradation (due to continuous use of the land, use of chemical fertilizers and pesticides etc can affect agricultural productivity through the following:

i. Increase in crop production costs for a certain level of output.
ii. The resultant changes in quantities of output and prices change the benefits received by consumers and producers. Initial levels of surplus compared with resultant levels enable estimation of the value of changes in the supply -of biodiversity resources.

The production .function technique is a natural complement to cost-benefit analysis. This method has been used to estimate the value of soil conservation (Pimentel *et al.,* 1994), of coastal wetlands (Aylward and Barbier 1992), of mangrove systems (Ruitenbeek 1992), flood-plains in northern Nigeria (Barbier *etal.1991)* etc. For more details refer Dixon *et al.,*. (1988).

Contingent Valuation Method

The basis for this method is what people are willing to pay (WTP) for increment in biodiversity quality, or what people are willing to accept (WTA) in compensation for foregoing such benefits. It is generally assumed that WTP is equal to WTA, but empirical research has demonstrated that WTA often exceeds WTP. In spite of this problem, economists use WTP to calculate the value of biodiversity. The "procedures involved are as follows:

- Elicit people's WTP for biodiversity goods or services directly through surveys/ questionnaires.
- Create a hypothetical market situation
- Use the respondent's replies to place value on biodiversity items that are not usually marketed.

The resultant valuation is 'contingent' because the value derived from this method depends on every individual's perception of number of background factors that influence the market under survey.

The advantages of this method are:

- It can be used to elicit values across the spectrum of total economic value.
- This is the only method available for arriving at option prices and existence value.

Disadvantages include the following:

- A poorly designed/implemented survey will not give the true WTP.
- There will tend to be differences between consumer intentions as expressed on the questionnaire and consumer preferences as revealed in the market.

The contingent valuation method was designed in North America and has been used there and in Europe; it has been little used in developing countries, except for Brazil.

Hedonic Pricing Method

Certain biodiversity services are non-marketable. However, the values of .these services are frequently incorporated into prices of marketable goods and services. Therefore, such market? Values must be desegregated to uncover the relative value of the two to human welfare. For example, soil fertility, scenic beauty or air quality of a land are_ not directly marketable, but-hedonic pricing method enables explicit valuation of these services that are implicit in the price of the land. The procedures involved in this method are as follows:

i. Estimate the value of the land.

ii. Estimate econometrically the value contributed by the chosen 'service' attributes to the value of the land.

iii. Work back from this hedonic price equation to the actual demand curve. For more details see Prescott-Allen and Prescott-Allen (1982).

Travel Cost Method

This method can be used to find only the recreational value of a landscape. The methodology involved in this technique is as follows:

i. Collect information on the expenditure incurred by visitors to the particular site/ landscape.

ii. Aggregate the number of visitors by what it costs them to travel to and from the site. This will provide a surrogate market indicating what people are WTP for access to the site.

iii. Estimate travel costs of visitors from distant places and nearby places. The WTP from these two groups of people will provide information on the relationship between distance and travel costs, based on which the benefits enjoyed by visitors to the site can be estimated.

The shortcomings of this method are:

i. Unobserved travel cost is quite likely.

ii. The method assumes that leisure time and travel to the site are necessarily a cost.

4 Biodiversity *vs.* Biotechnology

Since man learnt to domesticate plants for using them as a whole, or their products, more and more plants have been taken for cultivation or are being collected from the wilderness for use. This has resulted in the unequal distribution of species in different regions, receiving anthropogenic pressure of differing intensity. More-frequent use of certain plant species, through collection from natural vegetation, is causing the shrinkage of their germplasms and overall reduction of biodiversity of the concerned region. Similarly, more importance on the high yielding varieties of important cultivated species has caused the shrinkage of the habitat for the existence and distribution of the traditional land races and the wild species. Now, with the development in the biotechnology, its application for protection and improvement of biodiversity has become a new area of research.

Biotechnology is defined as "any technological application that uses biological systems, living organisms or derivatives thereof/to make or modify products or processes for specific use". Thus, the chief and critical raw material for biotechnology is biodiversity. Many modern technologies, including recombinant DNA technologies, genetic engineering, transgenics, and cell and' tissue culture protocols, are employed to obtain newer and newer benefits for human beings. The relationship between biotechnology and biodiversity is multidirectional

- Biotechnology provides very powerful tools for the critical assessment of biodiversity-genetics, species, and ecosystems, and consequently, the identification of potential bioresources themselves.
- It gives newer methods and guidelines for the conservation of biodiversity, all aiming at utilising the conserved resources in a sustainable manner for the benefit of mankind.
- It enhances the wise and efficient utilisation of bioresources, both as a genetic resource for production and in the remediation of altered/degraded ecosystems.

In other words, the increasing application of biotechnology and molecular tools to biodiversity has greatly enhanced the value and availability of bioresouces, bioprocesses, and the generated products, for providing food and health care to man and his domesticated animals. This is particularly true with reference to:

- Increased availability of food, feed and other renewable raw materials.
- Improved human health and hygiene.
- Greater protection of the environment.
- Enhancement of biosafety and environment friendly technologies (UNEP 2001).

Biotechnological processes for bioresource assessment

Bioresources are defined as materials of biological origin that are used for the economic betterment of human society through their trade as food, feed or pharmaceuticals. Biotechnological tools enable critical analysis of the diversity of such bioresources (organic compounds) present in living organisms. The latter contribute to a wide variety of environmental services, such as regulation of the gaseous composition of the atmosphere, protection of coastal zones, regulation of the hydrological cycle and the climate, generation and conservation of fertile soil, dispersal and breakdown of wastes, and absorption of pollutants. Many of these services have neither been recognised, nor properly valued-in economic terms. Of an estimated number of 1.75 million described species (Table 4.1), their utilisation is restricted to very few species and many have not yet, been applied for economic development (UNEP-WCMC 2000). The progress in biotechnology has provided the technical knowledge to get the maximum benefit from the existing biodiversity, as well as to improve the quality of the resources.

Table 4.1: Estimated number of described species on the earth

Kingdom	No. of described species (x 1000)
Bacteria	4
Protoctists (algae, protozoa, etc.)	80
Animals: Vertebrates	52
Animals: Invertebrates	1272
Fungi	72
Plants (excluding Algae)	270
Total described species	1750
Possible no. of species existing pn the earth	14000

Source: UNEP-WCMC (2000)

The development of very sensitive and highly specific bioassays to detect even proogram quantities of potentially useful organic molecules and compounds and automated screening technology, allow screening of thousands of plant, animals and microbial samples at a very quick pace, and efficient on selection those with value in pharmaceutical, agrochemical, food, cosmetic and other industries. We also now possess the expertise to analyse the diversity available in the DNA molecule that controls the production of novel compounds. DNA sequences of several organisms are being unravelled and sperialised methodologies have been developed to analyse and identify specific gene products. The genetic diversity and its potential have been studied in several species to date, (Amaral 2001; Ratnam 2001) and some species of critical importance have been fully sequenced to use the information for the development and better use of the same as well as the related species. We are now better equipped to delineate one species from another and accurately estimate the diversity within and between species. This has given us the-opportunity and the technical knowhow to produce hybrids between highly unrelated species (in terms of sexual incompatibility), which could not be possible by conventional breeding methods. Recent data have indicated that genetic variations do not always correlate with phenotypic or chemotypic variations and hence, biodiversity should be best assessed only on genetic grounds and not exclusively on phenotypic characteristics. Taxonomic systems based on DNA and RNA sequencer data "or on the basis of variations in gene products should hereafter, form the main basis for biodiversity characterisation and assessment.

Biotechnological tools have enabled identification of desirable and elite genes: locked-«p in wild relatives of domesticated plants, animals and microbes. They have further made possible the specific transfer of such genes to domesticated taxa, to produce transgenics that have increased performance, productivity and resistance to abiotic and biotic stresses of all kinds. For example, medium chain fatty acids, such as lauric acid, form the major source of dietary and industrial oils in the tropics. The production of this fatty acid in seeds is controlled by a specific protein called *acyl carrier protein—BTE.* Cloning the DNA of the gene coding for this protein *fiom Umbe Uularia californica* and its introduction into other oil-seed plants, can substantially increase the level of laurate (Voelker *et al.*, 1992). Other notable examples of useful genes identified and mapped usmg[v]biotechpology are: Genes responsible for the production of useful variants in coin identified through the use of quantitative trait loci (QTL) and evolutionary history, hitherto undiscovered genes from wild relatives of potato and tomato (Tanksley and McGough, 1997) and several new useful genes in rice and corn and their wild relatives (McCouch, 1998). The most notable achievement is the development of virus resistance in the cultivated maize by transfer of a family of genes from the Mexican perennial wild maize Zea *diploperennis.*

Biotechnology in *ex situ* conservation of biodiversity

Biotechnology can also play an important role in culturing and conserving biodiversity. In *ex situ* situations, it provides newer opportunities. A new class of non-living collections of living organisms, in the form- of DNA libraries (of naked DNA and genomic and cDNA as well as isolated chromosomes) and sequence databases has been made possible to keep alive the hope of their regeneration in future. The attempt to regenerate the extinct Tasmanian tiger is a major progress in the direction of regeneration of the lost biodiversity. These profoundly increase the option values of genetic resource collections, since the latter are the bases of agricultural development, as well as for providing health care. Such *ex situ* collections are invariably desirable from plants and animals, especially wild relatives of domesticated plants /microbes and land races, threatened to different extents (critically endangered, endangered and vulnerable); Such collections can be attempted after genetically characterising the wild relatives/land races through RFLP, RAPD (and its modifications) and allozyme techniques and ascertaining their option values for possible future use in improving domesticated taxa. Although, DNA banks are not substitutes for other conservation methods, they have the distinct advantage of requiring minimum space.

The other biotechnological methodologies exploited for *in situ* conservation of plants include rapid multiplication in a very short time using micropropagation, cryopreservation of vegetative or sexual propagules, synseed technology, etc. Under *in situ* situation, application of biotechnology provides data critical for the best management solutions for conservation of the target species. These data allow assessment of optimal or minimal population sizes for maintaining diversity, so that augmentation can be done to increase the population size through transfer from wild populations or through intense breeding programmes.

Field Gene Banks

This is one of the major methods of *ex situ* maintenance of taxa that must be conserved. A field gene bank is an area of land where collections of growing plant species needing conservation are assembled. The assemblage contains as many individuals of the target species as possible, in order to sustain genetic diversity. These field gene banks make available plant material for breeding, reintroduction, research, especially in population genetics, physiology, microbiology, biochemistry, nutrition and processing technology, and for several other purposes.

Field gene banks are particularly useful in the conservation of perennial species and therefore, are of greatest importance in forestry. They have also been established in agriculture/plantation sectors providing the required germplasm of such tropical crops, as cocoa, coconut, rubber, mango, cassava, coffee, banana, sweet potato and yam. The IBPGR has initially established/promoted 23 field gene banks for crops. Several of these also contain germplasms of wild relatives of domesticated crops. The characterisation and documentation of germplasm resources in a field gene bank consists of five operational procedures, as follows (IBPGR 1991.

i. Establishing the origin of the plant material: This is called Passport data. Passport data includes accession data, if an accession has been received from a breeder, another institution, etc., along with details on site of origin, ancestor or pedigree. It will also include collection data if the accession is directly derived from a field collection, along with a description of the collection site.

ii. **Characterisation:** This includes recording all highly heritable and easily identifiable characters of the plant, especially from a fully mature plant. These characters, often called Descriptors, must be those that are expressed in all environments.
iii. Preliminary evaluation: It includes details on plants' development and recording of characters expressed by the growing plant.
iv. Further evaluation: This includes recording all the reactions of plants to physical stresses - and to pathogens and predators.
v. Management data: This includes handling of the genetic resource, its distribution/exchange, regeneration and maintenance etc.

Over the years, the global network of base collections' has swelled to about 50 institutions, all of which have accepted IBPGR's invitation to participate actively in this network. Now, more than 100 species are being conserved in field gene banks throughout the world. The institutions include some of the International Centres of Agricultural Research (IARCs) and some national centres. The total number of accessions of PGRFA conserved in field banks is about a million at present. The advantage of field gene banks is their provision of materials readily accessible for utilisation and evaluation. A major disadvantage is possible reduction in genetic diversity of the material, thereby increasing its susceptibility to pests and diseases. Furthur more, field gene banks involve large areas of land/which limits the genetic range of the material that can be held.

Seed Banks

The seeds are stored in a seed bank for a considerably long period, without being used, in a viable condition. The aim is to preserve a large amount of species, in a viable state, for posterity. This has emerged as a very good device for conservation of plants of the habitats that are undergoing rapid changes and when the existence of the plant in its natural habitat is threatened. Conservation is both the safest and the cheapest if life processes are reduced to a low level, and seed preservation in seed banks fulfils this requirement admirably: Conservation through seed storage aims to preserve as much as possible the genetic integrity of individual or populations of a species. Although frequencies of genotypes or alleles may undergo inevitable changes due to storage, gene or allele erosions are minimised, and recombination with alien material is avoided. Preclusion or reduction in natural selection, genetic drift, natural hybridisation and destruction by parasites or loss through human error are also ensured. No other genetic effect has been observed.

A seed bank is one of the most efficient methods of *ex-situ* conservation for sexually reproducing species. Seeds, suitable for long-term storage are termed orthodox, conventional or desiccation-tolerant. Such seeds can be stored for a long time without substantial loss of vitality and without much genetic changes. Seeds, which cannot be stored in seed banks under the given conditions, are termed recalcitrant. Jackfruit, citrus, avocado, coffee/tea, maple, cinnamon, nutmeg, oak; chestnut, mango, cocoa, coconut and rubber belong to this category. It is difficult to conserve recalcitrant seeds. It is estimated that 20% of the world's total plants produce recalcitrant seeds that do not survive in low temperature and/or dehydrated conditions. They have no natural dormancy and die if not allowed to germinate immediately. It has also been found that the majority of orthodox seeds are either from temperate regions, where dormancy is enforced by cold winters, or from arid regions where dormancy is enforced by hot and dry climates. Rain forest seeds are often recalcitrant.

Among orthodox seeds, much importance is often given to small seeds, which occupy less space. The FAO constituted a panel of experts on plant exploration and introduction, which formulated certain standards and procedures for storage installations meant for long-term seed conservation. The recommended conditions for seed storage are -18°C or less temperature, use of airtight sealed containers, and a seed moisture content of 5-2%. The seed bank needs proper and continuous power supply. Medium-term storage can be effected at *6-VC* Storage at the temperature-of liquid nitrogen has given encouraging and problem-free results. It is also less costly than the conventional seed storage. However, the moisture content needs to be strictly controlled. Orthodox seeds can be kept under storage for very long periods at sub-zero degree centigrade, if previously dried to about 5 to 8% moisture content. Although longevity varies from taxon to taxon, orthodox seeds can be stored for 5 to 25 years at 0 to 5°C (medium-term storage) or for up to 100 years, if stored at -10 to -20°C (long-term storage). Drop in every one percent below 8%, invariably doubles the storage life of seeds, but drying to the level below 4% moisture level, causes biochemical damage of seeds and reduces their viability. For every 5°C drop in temperature, the life of the seed is doubled. For example, onion seeds with 10% moisture are viable for 16 weeks at 35°C, but will live for *78* years at *0°C.*Dropping the temperature further to-15°C would enhance seed longevity to 624 years (Koopowitz and Kaye 1990). Keeping these in mind, when both temperature and water content are judiciously reduced, these two factors multiply the life span of a seed.

Long-term seed storage requires regular regeneration tests in stored seeds to monitor their viability. The frequency of their germination/ regeneration depends on their initial viability and rate of loss of viability due to storage, and storage conditions. The minimum requirement for each regeneration test is 400 seeds. Some seed banks recommend 5% of the seeds stored to be subjected to regeneration tests. In large seed banks, regeneration tests are done continuously, on the seeds of one species or the other two types of seed storage are normally practiced in a seed bank. As per the first, base collections are stored under optimum conditions and are not interfered with, until reduced viability is noticed through periodic germination tests. When reduced viability is observed, new seed regeneration is carried out. In the second type of seed storage, active -collection of seeds is done, "from which subsamples can be taken periodically for experimentation, exchange, evaluation and display. The active collection need not necessarily be stored under optimum seed storage conditions and can be multiplied periodically, by growing a new generation of plants and by reharvesting. This collection acts as a source of genetic material for farmers and plant breeders for their utilisation.

While some seed banks specialise in the storage of seeds of taxa in specific geographic areas, others specialise in seeds of a particular taxonomic group. Some banks concentrate on the seeds of forest trees and some on specific crops. Nowhere is there any attempt to store the seeds of the weeds and the weedy relatives of the cultivated species, though it has been well: understood that many weeds contain numerous valuable genes that can be used for crop improvement.

It should be kept in mind that germplasm conservation through seed banks is not an immediate option for biodiversity conservation because the process does not give any importance to the habitat in which the species grow; it only comes as an alternative method when it is realised that there is no other way to conserve the germplasm *in situ.* In addition, it cannot be practiced for all seeds. It is also criticised because it 'freezes evolution' of plants; seed germplasms held in banks can no longer continuously adapt to changes in the environment, such as exposure to new races of pests or climatic stresses/changes.

'Test-tube' Gene Banks

Many plants either do not produce seeds (i. e., clonal crops) or are not normally reproduced from seeds, so as to maintain a highly heterozygous genotype, intact. To these categories, belong short-lived plants, which are propagated from tubers, bulbs, corms, rhizomes, roots, etc., as well as long-lived shrubs and trees, which are propagated vegetatively. These taxa are conserved through the maintenance of their vegetative propagules under appropriate conditions. Propagules of short-lived taxa have a storage life of only months, rather than years. Potatoes can normally be kept at 4°C, until the next spring or a further period of 12 months but not beyond. Most other roots and tubers have a storage life of less than 12 months. Cuttings of-shrubs and trees, either unrooted or rooted, can be stored between -2 and +2°C, up to a maximum of five years.

Culture and Callus Collections

The culture collections are the centres for storing the germplasm of mostly the microorganisms, bacteria, algae and fungi though the cells of the higher plants are stored as-suspension cultures. The cultures are maintained at a temperature range between 0-2Q°C, depending on its requirement and use. Liquid cultures are maintained, if the collection is meant for supplying materials for use for various purposes, while solid agar medium or other solid broths are used for long-term storage of the cultures. The cultures can also be stored in airtight small vials at. cryogenic temperature (-196°C in liquid nitrogen). The culture collection can store cells at the actively growing state and can perform regular sub-cultures to maintain cell viability. But the centres, which aim to preserve the organisms for longer duration, store the cells in a stationary state, as dormant cells or spores.

Callus collections store the calluses of any species that can develop proliferated callus in synthetic media. The calluses are regularly sub-cultured, and the duration of the callus storage differs with the plant species. In such cases, care is always taken to avoid aging of calluses, as this will induce cell fusion and polyploidy. The limitation of the callus collection and storage is that many species do not develop callus. In addition, many species produce callus, but do not successfully differentiate, thus making their storage useless. Nevertheless callus collections are being maintained in many laboratories and horticulture and floriculture firms, to maintain their germplasm and act as a store for suppling the materials regularly to the fields.

Pollen Banks

To make the germplasm conservation economical and to conserve many taxa in a limited space, as limited as a deep freezer, pollen storage can be a good option. Since it is now possible, at least in a few taxa, to raise whole plants as haploids from pollen grains, pollen banks have assumed additional importance. The pollens remain in their normal viable state and can be directly made available for use, for artificial fertilisation and breeding works, especially in breeding tree taxa. The major, disadvantage of a pollen bank is that only paternal material can be conserved and regenerated.

Pollen preservation can be made for prolonged periods through cryopreservation. If the moisture content of pollen is suitably reduced, according to the requirements of a particular species, pollen can be kept at cryogenic temperatures for periods ranging up to 6-12 years, but in the majority of species, mostly well below one year. Although the exact reasons for the loss of pollen viability/fertility, in a very short time under apparently good storage conditions, are not known, it is believed that the moisture content of pollen plays a very critical role. Therefore, cryopreservation for long-term pollen storage is unlikely to be within reach for general application, until the causes of pollen breakdown under storage are well understood. However, freeze- and vacuum-drying have both been successfully applied to storing pollen of a number of taxa, even up to 12 years, usually at a storage temperature of +5 to -18°C.

DNA Banks

A DNA bank may be defined as a 'gene library' in which samples of DNA extract are stored. This provides a new option for accession of plant germplasm (Adams *et al.,*. 1994). The DNA samples are of three kinds: i) total genomic DNA, u) DNA libraries, and iii) individual cloned DNA fragments, including RFIP probes, mini- and microsatellites, etc. Samples of the first type are made with DNA isolated directly from plant tissues. The DNA library preparation requires another step, i.e. fragmenting the isolated DNA with a suitable restriction enzyme and packaging the diverse mixture of fragments into a suitable cloning vector. The purpose of a DNA library is to retain each fragment from the original DNA extract, so that the whole genomic DNA is represented in the mixture. The third type of DNA samples, as individual cloned fragments, are fixed and genetically pure since each vector molecule in the sample is host to the same DNA fragment.

Stored DNA samples ideally, serve two contrasting purposes:

- They are very convenient experimental materials that can be shipped immediately without quarantine problems and put to use immediately for further analysis and manipulation at the molecular level.
- They are ideally suited to a 'time capsule' approach to conservation. In other words they, are frozen genetic resources and potentially, the most stable form of preserved germplasm. They do not require recurrent regeneration to retain their future utility, indefinitely.

Concomitantly, DNA banks are afflicted with almost all the problems faced by seed banks, but more acutely. Proper, reliable documentation and labelling of DNA samples are very crucial to their use. In addition, the despatch, receipt and use of these samples require a high level of technical skill. Moreover, establishing: ownership and control of DNA samples is a complex 'delicate' problem. These factors limit the contribution DNA banks could make to the conservation of biodiversity. Furthermore, the sophistication of 'immobilisation' techniques and the potential power of PCR amplification methodologies notwithstanding, total genomic DNA samples are virtually non-renewable. Thus, DNA banks offer no newer solutions at least for the present, for the conservation of endangered species. DNA storage invariably only allows for recovery of single genes, but not of whole genomes.

In spite of the above problems, an international network of DNA banks (DNA Bank-Net) for the conservation of genomic DNA has been vigorously promoted (Adams 1993). There are three primary data bases that collect and distribute DNA material: Gene Bank (Bethesda, Maryland USA), EMBL (Cambridge,UK) and the DNA Data Bank of Japan (Mishima, Japan). The main aim of such a network is to make biological resources more widely available for human benefits, through .increased research work and use. However, it should be understood that it is only an adjunct and not an alternative methodology in conservation. So, a DNA bank cannot replace a field gene bank, despite being less costly than the latter.

***In vitro* Conservation Methods**

This form of conservation is very important and is followed throughout the world by many institutions. Most of the *in-vitro* methods have several advantages, such as greater safety from viral attack, lower cost and accommodation of larger numbers. All the methods involve storage of plant germplasms under *in vitro* conditions. Meristem tips and buds are usually stored; such storage is especially followed for those taxa whose seeds are recalcitrant. Very often, the meristems or buds from intact plants or the adventive 'embryos' produced directly from *in-vitro* grown explants or calli, are coated with materials such as alginate or neutral gums and stored.

Biotechnology and its role in the utilisation of biodiversity

Application of biotechnology provides greater and efficient means of utilising the available biodiversity, keeping in mind the conservation and improvement of the available resources. Some of the areas of the application of biotechnology in biodiversity utilisation are:

i. Transgenic organisms can be used as sources of proteins and peptides (structural and storage proteins, hormones such as insulin, antibodies and all categories of enzymes), lipids and fatty acids (edible and industrial oils, essential oils), carbohydrates, (cellulose, agar, pectins and glues, chitin, many monosaccharides) and secondary metabolites (diverse metabolites that find use as pharmaceuticals, food additives, colorants, flavours and aromas, condiments, biopesticides, etc.).

ii. Organisms can be targeted to specific end users through application of genetic engineering, breeding and *in-vitro* culture systems, such as enhancing agronomic performance in yield, disease resistance, stress tolerance, etc. A major objective of modern agriculture is to improve yield, both quantitatively and qualitatively. Two factors that greatly affect yield are diseases and abiotic stresses. These two can be overcome through, biotechnological means, either by modifying the endogenous genes, or by introduction of new genes. The former can be done by induced mutagenesis, while the latter easier method can be effected by utilising genes, already existing in the gene pools of various categories (i.e., primary to quaternary), and introducing the same via 'marker assisted' breeding or genetic engineering. More and more useful genes are being unravelled, especially from microbial sources. The best examples are: the heat stable *Taq* polymerase from the bacterium *Thermus aquaticus* that has revolutionised the field of biotechnology and genetic engineering; the endotoxin *Bt* gene from *Bacillus thuringiensis* for insect resistance, the *basta* herbicide resistance gene from *Streptomyces hygroscopicus* and a ribonuclease gene for male sterility from *Bacillus amyloliquefaciens.*

iii. We can improve, maintain or rehabilitate our environment effectively through identification of soil microbes, through DNA fingerprinting, that are elite with reference to nitrogen fixation (bacteria, cyanobacteria), phosphate solubilisation (bacteria, mycorrhizae), mineral leaching (bacteria), pollutant degradation, etc. Further engineering and transferring of the key microbial - genes involved in the enrichment or cleaning up of soil or water can be subsequently done. Biodiversity is the key resource for the rehabilitation and remediation of degraded and contaminated ecosystems. Biotechnology can become helpful in rehabilitation, for example, genetic characterisation of endo, ecto orchid and ericoidmycorrhizal fungi, and rhizobia and other nitrogen fixers can be made, which may be important, as inoculants, for reforestation/afforestation of degraded lands or lands, subjected to a lorig history of intensive cropping.

iv. Environmental clean-up can be done by suitable microbial systems because bioremediation can be carried out *in situ,* eliminating or greatly reducing costs, and the microbes multiply at the expense of the pollutants, thereby naturally enhancing the remediation rates. However, the problems that may be encountered, which may greatly affect the remediation processes are **a)** lack of an adequately known organism, capable of thriving on the pollutant and utilising it as an energy source, **b)** limiting environmental features, and **c)** absence of appropriate microbes at the particular pollutant site. The limiting environmental features may include soil toxicity, extreme acidity / alkalinity, presence of anaerobic conditions, pressure of other highly competitive microbes, etc. These problems notwithstanding, microbes which hold promise for affecting a variety of bioremediation processes have been identified. We have anaerobes that can grow on toluene, ethylbenzene, xylene and other BTEX class of pollutants. We also have microbes that have the capacity for chlororespiration using the dechlorination of a chlorinated substrate as the electron acceptor for energy generation and growth (i.e., organisms that can grow on tetrachloroethane, chlorinated benzoate and chlorinated phenol). The bioremediation process, however, cannot be completely carried out by inoculating/introducing a single microbe; it requires either a consortium of microbes, or the construction, through genetic engineering, of organisms with an amalgam of desirable traits. For example an organism that grows on the explosive material, trinitrotoluene (TNT) was recently constructed; it has the capacity to remove the nitro groups from TNT. To this, was added a plasmid that has the ability to grow on toluene (Duqueet *et al.,*. 1993).

v. Identification and use of plants and microbes, that are naturally capable of accumulating high doses of heavy metals such as lead, cadmium, zinc, mercury, chromium, has been successfully made. Metal chelating, metal accumulating and bioleaching microbes are now available to clean the metal contaminated soil and to recover metals and minerals from the low-grade ores, that were till now considered as useless materials. Hyper-metal accumulating grasses and tree species are now available for plantation in the metal contaminated soils.

vi. Production of biosurfactants, bioplastics and other biodegradable products from microbes and further improving the latter's efficiency by suitable modification of the biosynthetic pathways involved in the production of such substances, are the new areas of biotechnology. Some promising surfactants and polymers, such as the xanthan gums are produced by the bacterium *Xanthomonas campestris* (Zajic and Mahomedy 1984), which can be applied in petroleum recovery processes. The critical characteristic of these polymers is their substantial viscosity, combined with flow characteristics that allow them to pass through small pore spaces. These materials are produced by conventional fermentation processes and are injected as additives in water-flooding operations.

vii. Overcoming interspecific and intergeneric barriers in plants, through *in vitro* cultures, *in vitro* fertilisation, parasexual hybridisation, embryo rescue, etc., are possible at present, and superior hybrids can be produced between two sexually incompatible species. *In vitro* culture can also increase diversity through somaclonal and gametoclonal variations or through *in-vitro* mutagenesis.

viii. Cell and tissue culture technology could be used for the industrial-level production of pharmaceuticals (alkaloids steroids, flavoribids, terpenoids, enzymes, etc.), food additives (carotenoids, anthocyanihs, betanins, phenotics), perfumes (rose, jasmine, lavender, sandalwood oil, agarwood oil, *agil*, etc.), biopesticides (pyrethrum), polysaccharides, proteins and lipids, etc. There is scope for, not only increasing the efficiency of production of these substances *in vitro*, but also for manipulation of biogenetic pathways of primary and secondary metabolism. The latter has been especially exploited, either for the production of an intermediary compound in a metabolic pathway (for example, vanillin in the lignin biosynthetic pathway), or for biotransformation (i.e., converting one intermediary product of a metabolic pathway into another more useful product) through stereospecific reactions, such as hydroxylation, oxidation, hydrolysis, isomerisation and dehydration. As examples of the latter, the production of betamethyldigoxin and a number of monoterpenes may be cited.

The CBD in Article 8(g) calls for measures to 'regulate, manage or control the risks associated with the use and release of living modified organisms resulting from biotechnology, which are likely to have adverse environmental impacts that could affect the conservation and sustainable use of biological diversity, while also taking into account the risks to human health. The CBD further advises, in Article 19.3, its signatory countries to safely handle and use any genetically modified organism (GMO).

Interest in research on the potential effects, of the release of genetically modified organisms, on biodiversity is accelerating. Introduction of GMOs into natural and homeostatic ecosystems is likely to cause the loss of species and habitat diversity; at least there is a strong theoretical possibility for this. Adverse biological effects on non-target populations and ecological and evolutionary disruption may be either the direct result of the introduced transgene or alternatively the indirect result of the changing socioeconomic conditions, related to the application of recombinant technologies.

Several direct non-target effects on beneficial and native organisms by GMOs have been reported, An example is the transgenic Bt cotton plant (raised to resist the cotton bollworm), which affects a wide array of non-target insects, such as butterflies, moths and beetles. Some GM crops have been shown to affect soil ecosystems by decreasing the rate of decomposition of organic wastes, affecting carbon and nitrogen levels and decreasing the diversity of soil microbial populations. Another possible direct impact of GMOs, raised for conferring viral resistance is the likely emergence of new viruses with new biological characteristics through recombination and heteroencapsidation (Wolfenberger and Phifer, 2000).

GMOs can cause harm to biodiversity, due to the properties of the transgenes *per se* or their transfer and expression in non-target organisms. Adverse impacts on biodiversity "through the introduction of GMOs may also result" from" disturbance of the dynamic population equilibria of ecosystems. Enhanced ability df GMOs to invade natural habitats of native species may lead to reduction of the population size of native taxa and, in extreme cases, to the total elimination of the populations of certain species, especially threatened ones (Edge 1.99.4).. The most important factors augmenting the hazard potential of GMOs are their increased fitness, adaptation to a wide variety of environmental conditions, instability of transgenes, resistance/avoidance to predation and favourable econiche (Strauss, 1991).

The highly invasive nature of transgenic crops is considered a perceivable risk and many examples support this probability. The transgene reportedly enhances the invasive property of a species (Wolfenberger and Phifer, 2000). The transgenic salt-tolerant rice is known to escape from its confinement and to extensively invade saline areas. Many engineered crops also turn into weeds in agricultural and non-agricultural fields (Tomiuk and Loescheke, 1993). The transgenic crops may become uncontrollable in subsequent cropping by producing more persistent 'volunteer' plants, or the transgene may be transferred to its sexually compatible wild species /relatives, resulting in the production of more persistent weed populations. Gene flow has been found to occur between rice and perennial- wild rice, maize and teosinte, sugar-beet and wild beet, alfalfa and its wild relative, etc. (Dale, 1994). In view of this, the effects of introducing transgenic plants with conferred disease resistance, pest resistance, herbicide/pesticide/fungicide tolerance, environmental stress tolerance, etc., would have to be very seriously considered as a part of risk assessment and biosafety measures, before field trials and commercialisation of transgenic crops are attempted.

Risk assessment, consequent to the release of a GMO, is not easy and involves several sequential steps:

- **i.** *A priori* identification of the potential/ documented hazards.
- **ii.** Estimation of their relative importance.
- **iii.** Computation of the probability of adverse impacts (UNEP, 2001). The impacts probability and its quantification are hardly feasible in the case of biodiversity Mathematical modeling approaches may help, but are only approximations to real situations.

Hence, risk assessments are often done individually for every GMO released, taking into consideration data obtainable from characterisation- of the host organism, methods of transgenesis, characterisation of the GMO, intended use/effect of the GMO, ecological relevance of the intended effect of the release, etc. Based on the results of risk assessment, GMOs are classified as low, intermediate or high risk organisms. Certain important measures have been suggested for minimising the direct impacts of GMOs; For transgenic crop plants/ the measures suggested are:

- **i.** Elimination or disarmament of the biological vectors, once transgenics are produced, to arrest the potential for further vector-mediated gene transfer.
- **ii.** Deletion, of the pathogenic sequences contained in some vectors such as *Agropacterium tumefaciens* Ti plasmid to preclude the possibility of their survival and transmission.

iii. Control of dispersal of the traasgenie crop, beyond the test" site through reproductive isolation. (UNEP 1995). For microbial GMOs, the measures suggested for minimising their direct impacts differ, because the possibility of horizontal gene transfer cannot always be excluded. The measures suggested xelaterinainly to minimising dispersal of the transgene.

Another direct impact of biotechnology could be episodic genetic erosion/ which would threaten the genetic diversity on which this technology depends. For instance, micropropagation and the consequent production of identical clones discourage perpetuation of genetic diversity through evolutionary adaptations. GMOs can cause direct impacts on target organisms and indirect impacts on non-target organisms. A clear case of this duality of impact was reported by Watkinson *et al.* (2000) in regard of the elimination of the weed *Chenopodium album*, a menace in sugar-beet fields. But this has indirectly reduced the population of a particular species of frugivorous bird, whose main food is the seed of this feed. Pesticidal proteins produced by GMOs may have effects indirectly through bioaccumulations; when predators consume prey items that contain pesticidal proteins, they ingest the latter (Wolfenberger and Phifer, 2000).

Indirect impacts of biotechnology are immense and of very great relevance to people, in developing countries, who rely directly on biodiversity for their daily sustenance. These are, however, predominantly socioeconomic ones, operated through human economic and social systems. The impacts themselves are the results of human responses to the changes in relative cost and prices of biotechnologically derived items. Knowledge about the use of different species that exist mostly in the wild would raise the value of that material, resulting in increased collection pressures on that plant, which in turn would lead to overexploitation and species loss. Value increases of biotechnologically-derived items can' increase the interest and conflict over ownership of genetic resources, the rates at which these resources should be utilised, IPRs, and formulation of laws relating to access to the resources.

Conclusion

While it is true that biotechnological exploitation of biodiversity has both positive and negative impacts, an optimistic consideration is to make best use of the knowledge of biotechnology for the conservation of the biodiversity. In general, the data suggest that despite a variety of initiatives, biodiversity continues to decline. Most examples of successful conservation action are those, where particular attention and considerable financial resources have been focused on individual species or localised areas. Many threats to biodiversity, such as habitat modification and natural invasion or artificial introduction, continue to intensify. With the rising interest in biotechnology and the progress made in the field, the gained knowledge can be used to make better utilisation, as well as conservation of bioresources.

5 Biodiversity *vs.* Bioproductivity

When you think farms in Kansas, you probably picture seemingly endless fields of wheat or corn plowed up and planted each year. By 2040, the picture might change, thanks to pioneering research at the nonprofit Land Institute near Salina, Kansas. The institute headed by plant geneticist Wes Jackson, is experimenting with an ecological approach to agriculture on the midwestem prairie. This approach relies on planting a mixture of different crops in the same area, a technique called polyculture. This involves planting a mix of perennial grasses (Figure 5.1, left), legumes (a source of nitrogen fertilizer, Fig. 5.1, right), sunflowers, grain crops, and plants that provide natural insecticides in tile-same field.

Figure 5.1: Solutions; the land institute in Salina, Kansas is a farm, a prairie laboratory, and a school dedicated to changing the way we grow food. It advocates growing a diverse mixture (Polyculture) of edible perennial plants to supplement traditional annual monoculture crops. Two of these perennial crops are eastern gamma grass (left) and the Illinois bundle flower (right).

The goal is to grow food mimicking many of the natural conditions of the prairie without losing fertile grassland soil. Institute researchers believe that *perennial polyculture* can be blended with *modern monoculture* to reduce its harmful environmental effects. Because these plants are perennials, there is no need to plow up and prepare the soil each year to replant them. This takes much less labor than conventional monoculture or diversified organic farms that grow annual crops. It also reduces soil erosion because the unplowed soil is not exposed to wind and rain, and it reduces the need for irrigation because the deep roots of such perennials retain more water than annuals. There is also less pollution from chemical fertilizers and pesticides.

Thirty-three years of research by the institute have shown that various mixtures of perennials grown in parts of the midwestern prairie could be used as important sources of food. One such mix of perennial crops includes eastern gamma grass (a warm-season grass that is a relative of corn with three times as much protein as corn and twice as much as wheat; Figure 5.1, left), mammoth wildrye (a cool-season grass that is distantly-related to rye, wheat, and barley), Illinois bundkflower (a wild nitrogen-producing legume that can enrich the soil and whose seeds can serve as livestock feed; Figure 5.1, right) and Maximilian sunflower. (This produces seed with as much protein as soybeans).

These discoveries may help us come closer to producing and distributing enough food to meet everyone's basic nutritional needs without degrading the soil, water, air, and biodiversity that support all food production. There are two spiritual dangers in not owning a farm. One is the danger of supposing that breakfast comes from the grocery, and the other that heat comes from the furnace.

How food is produced?

What Three Systems Provide Us with Food? Some Good and Bad News Historically, humans have depended on three systems for their food supply. Croplands mostly produce grains and provide about 76% of the world's food. Rangelands produce meat, mostly from grazing livestock, and supply about 17% of the world's food. Oceanic fisheries supply about 7% of the world's food. Some good news is that since 1950 there has been a staggering increase in global food production from all three systems. This phenomenal growth in food productivity occurred because of technological advances such as increased use of tractors and farm machinery and high-tech fishing boats' and gear; inorganic chemical fertilizers; irrigation; pesticides; high-yield varieties of wheat, rice, and corn; densely populated feedlots and enclosed pens for raising cattle, pigs, and chickens; and aquaculture ponds and ocean cages for raising some types of fish and shellfish.

To feed the world's 9.3 billion people projected by 2050, we must produce and equitably distribute more food trian has been produced since agriculture began about 10,000 years ago and do this in an environmentally sustainable manner. Some analysts believe we can continue expanding the use of industrialized agriculture to produce the necessary food.

Some bad news is that other analysts contend that environmental degradation, pollution, lack of water for irrigation, overgrazing by livestock, overfishing, and loss of vital ecological services (Figure 5.1-5.2) may limit future food production. A key problem is that human activities continue to take over or degrade more of the planet's net primary productivity, which supports all life. This chapter analyzes the advantages and disadvantages of the world's current crop, meat, and1 'fish production systems and how these systems can be made more sustainable.

What Plants and Animals Feed the World?

The earth has perhaps 30,000 plant species with parts that people can eat. However, only 15 plant and 8 terrestrial animal species supply an estimated 90% of our global intake of calories. Just three grain crops – wheat, rice, and corn provide more than half the calories people consume. These three grains, and most other food crops, are *annuals,* whose seeds must be replanted each year.

Two thirds of the world's people survive primarily on traditional grains (mainly rice, wheat, and corn), mostly because they cannot afford meat. As incomes rise, people consume more grain, but indirectly in the form of meat (mostly beef, pork, and chicken), eggs, milk, cheese, and other products of grain-eating domesticated livestock. Fish and shellfish are art important source of food for about 1 billion people, mostly in Asia and in coastal areas of developing countries.). But on a global scale fish and shellfish supply only 7% of the world's food, less than 6% of the protein in the human diet, and 1% of the energy in the human diet.

What Are the Major Types of Food Production?

All crop production involves replacing species rich late successional communities such as mature grasslands and forests with an early successional community consisting of a single crop or a mixture of crops *(poly culture).* The two major types of agricultural systems are industrialized and traditional. Industrialized agriculture, or high input agriculture, uses large amounts of fossil fuel energy, Water, commercial fertilizers, and pesticides to produce huge quantities of single crops (monocultures) or livestock animals for sale. Practices on about 25% of all cropland, mostly in developed countries (Figure 5.2), high-input industrialized agriculture has spread since the mid-1960s to some developing countries.

Plantation agriculture is a ford of industrialized agriculture used primarily in tropical developing countries. It involves growing cash crops (such as bananas, soybeans, sugarcane, cocoa, and vegetables) on large monoculture plantations, mostly for export and sale in developed countries. An increasing amount of livestock production in developed countries is industrialized. Large numbers of cattle are brought to densely populated .*feedlots,* where they are fattened up for about 4 months before slaughter. Most pigs and chickens in developed countries spend their entire lives in densely populated pens and cages and are fed mostly grain grown on crop land.

Traditional agriculture consists of two main types, which together are practiced by about 2.7 billion people (43% of the world's people) in developing countries and provide about 20% of the world's food supply. Traditional subsistence agriculture typically uses mostly human labor and draft animals to produce only enough crops or livestock for a farm family's survival. Examples of this very low-input type of agriculture include numerous forms of shifting cultivation in tropical forests and nomadic livestock herding (Figure 5.2).

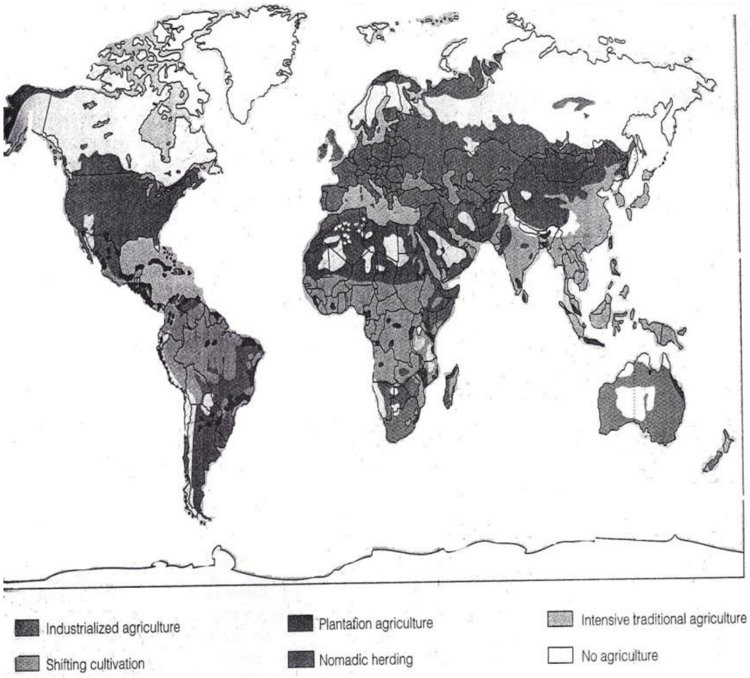


Figure 5.2: Locations of the world's principal types of food production. Excluding Antarctica and Greenland, agricultural systems cover almost one third of the earth's land surface and account for an annual output of food worth about $1.3 trillion

In traditional intensive agriculture, farmers increase their inputs of human and draft labor, fertilizer, and water to get a higher yield per area of cultivated land. They produce enough food to feed their families arid to sell for income. Croplands, like natural ecosystems, provide ecological and economic services (Figure 5.3).

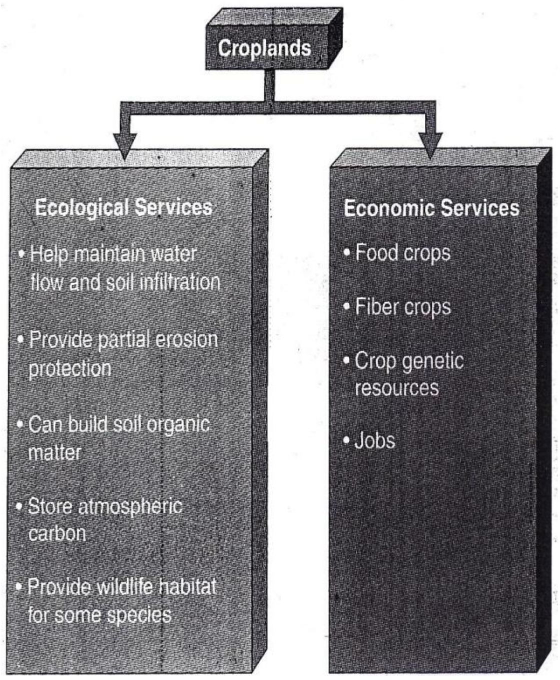


Figure 5.3: Natural capital, ecological and economic services provided by croplands

Producing food by green revolution and traditional techniques

How Have Green Revolutions Increased Food Production? High Input Monocultures in Action Farmers can produce more food by farming more land or getting higher yields per unit of area from existing cropland. Since 1950, most of the increase in global food production has come from increased yields per unit of area of cropland in a process called the green revolution.

This green revolution involves three steps. First, develop and plant monocultures of selectively bred or genetically engineered high-yield varieties of key crops such as rice, wheat, and corn. Second, produce high yields of these crops by using large inputs of fertilizer, pesticides, and water. Third, increase the number of crops grown per year on a plot of land through multiple cropping. This high-input approach dramatically increased crop yields in most: developed countries between 1950 and 1970 in what is called the first green revolution (Figure 5.4).

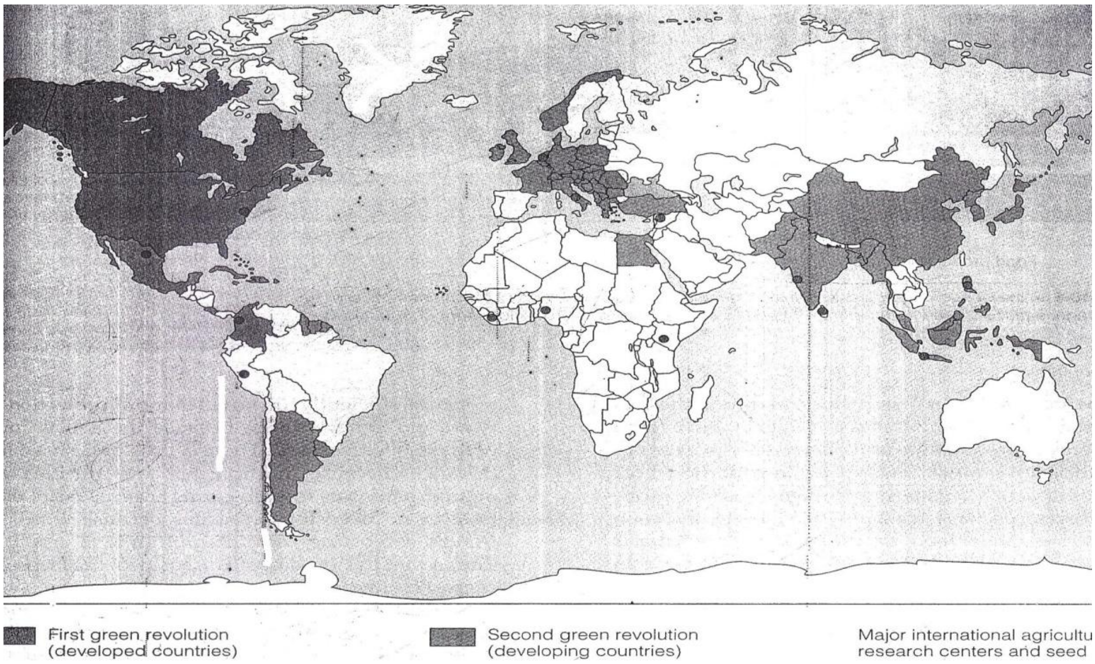


Figure 5.4: Countries whose crop yields per unit of land area increased during the two green revolutions. The first (blue) took place in developed contries between 1950 and 1970; the second (green) has occurred since 1967 in developing countries with enough rain fall or irrigation capacity. Several agricultural rsearch centers and gene or seed banks (red dots) play a key role in developing high yield crop varieties.

A second green revolution has been taking place since 1967 (Figure 5.4) by introducing fast-growing dwarf varieties of rice and wheat, specially bred for tropical and subtropical climates, into several developing countries with enough fertile soil and fertilizer, water, and pesticides, yields of these new plants (Figure 5.5) can be two to five times those of traditional wheat and rice varieties. The fast growth also, allows farmers to grow two or even three crops a year (multiple cropping) on the same land. Producing more food on less land is also an important way to protect biodiversity by saving large areas of forests, grasslands, wetlands and easily eroded mountain terrain from being used to grow food.

These yield increases depend not only on fertile soil and ample water but also on high inputs of fossil fuels to run machinery, produce and apply inorganic fertilizers and pesticides, and pump water for irrigation. All told, high-input green revolution agriculture uses about 8% of the world's oil output.

Figure 5.5: Solutions; Ahigh yield variety of rice developed in the second green revolution

Case Study: Food Production in the United States In the United States industrialized farming has become agribusiness as big companies and larger family owned farms have taken control of almost three-fourths of U.S. food production. Only about 650,000 Americans (2% of the population) are full-time farmers. However, about 9% of the population is involved in the U.S. agricultural system, from growing and processing food to distributing it and selling it at the supermarket.

In terms of total annual sales, agriculture is bigger than the automotive, steel, and housing industries combined. It generates about 18% of the country's gross national product and 19% of all jobs in the private sector/ employing more people than any other industry. Here are three pieces of good news about the highly productive industrialized agricultural system in the United States. First, with only 0.3% of the world's farm labor force, U.S. farms produce about

17% of the world's grain (most consumed by U.S. 'livestock) and nearly half of the world's grain exports.

Second, since 1-950, U.S. farmers have used green revolution techniques to more than double the yields of key crops without cultivating more land. Indeed, the amount of land used to grow crops in the United States decreased by 23% between 1950 and 2000. Such increases in the yield per hectare of key crops have kept large areas of forests, grasslands, wetlands land easily erodible land from being, converted to farmland.

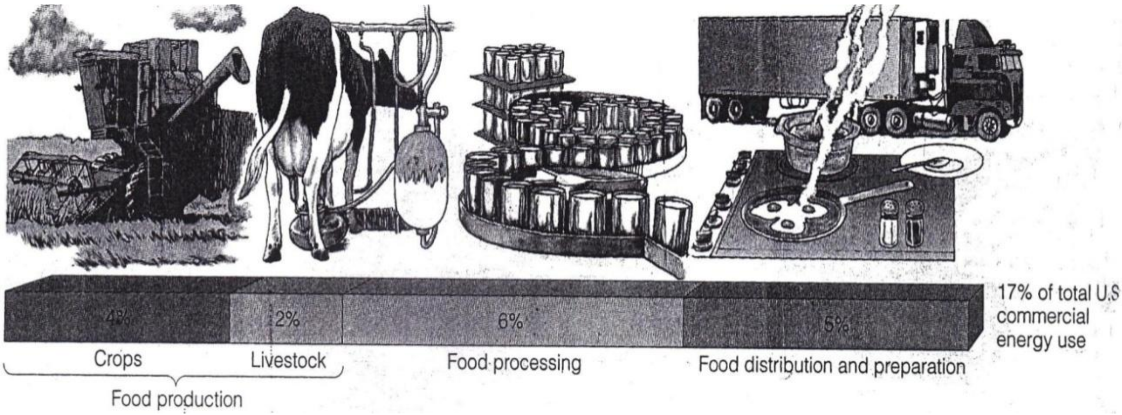


Figure 5.6: in the United States, industrialized agriculture uses about 17% of all commercial energy. On average, a piece of food eaten in the United States has traveled 2,100 kilometers (1,300 miles)

Third, the country's agricultural system has become increasingly efficient. While the U.S. output of crops, meat, and dairy products has been increasing steadily since 1975, the major inputs of labor and resources with the exception of pesticides-to produce each unit of that output have fallen steadily since 1950.

The bad news is that if we include livestock, the U.S. food production system uses about three units of fossil fuel energy to produce one unit of food energy. That energy efficiency is much lower if we look at the whole U.S. food system. Considering the energy used to grow, store, process, package, transport, refrigerate, and cook all plant and animal food, about 10 units of nonrenewable fossil fuel energy are needed to put 1 unit of food energy on the table. By comparison, every unit of energy from human labor in traditional subsistence farming provides at least 1 unit of food energy and up to 10 units of food energy using traditional intensive farming.

What Growing Techniques Are Used in Traditional Agriculture? Low-Input Agro diversity in Action Traditional farmers in developing countries grows about 20% of the world's food on about 75% of its cultivated land. Many traditional farmers simultaneously grow several crops on the same plot, a practice known as interplanting. Such crop diversity reduces the chance of losing most or all of the year's food supply to pests, bad Weather, and other misfortunes.

Interplanting strategies vary. One type is poly varietal cultivation, which involves planting a plot with several varieties of the same crop. Another is intercropping. It involves growing two or more different crops at the same time on a plot (for example, a carbohydrate-rich grain that uses soil nitrogen and a protein-rich legume that puts it back). A third type is agro forestry, or alley cropping, in which crops and trees are grown together.

A fourth type is polyculture. It is a more complex form of intercropping in which many different plants maturing at various times are planted together. Low-input polyculture has a number of advantages. There is less need for fertilizer and water because root systems at different depths in the soil capture nutrients and moisture efficiently. It provides more protection from wind and water erosion because the soil is covered with crops year-round. There is little or no need for insecticides because multiple habitats are created for natural predators of crop-eating insects. Also there is little or no need for herbicides because weeds have trouble competing with the multitude of crop plants. The diversity of crops raised provides insurance against bad weather.

In addition, recent ecological research found that on average, low-input polyculture produces higher yields per hectare of land than high-input monoculture. For example, a 2001 study by ecologists Peter Reich and, David Tilman found that carefully controlled polyculture plots with 16 different species of plants consistently out produced plots with 9, 4, or only 1 type of plant species. Wes Jackson is using poly culture to grow perennial crops on prairie land in the United States.

Food production, nutrition, and environmental effects

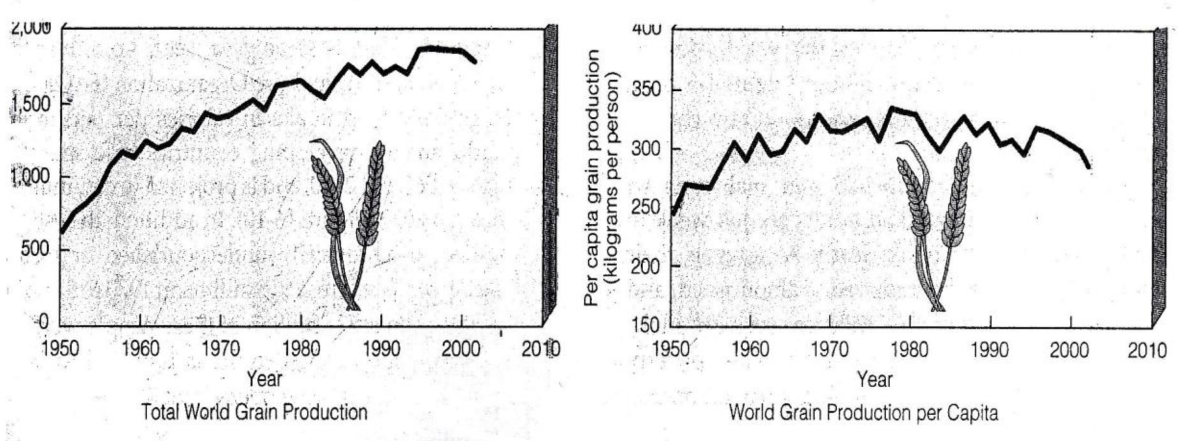


Figure 5.7: Good news; total worldwide grain production of wheat, corn, and rice (left) and percapita grain producton (right), 1950-2002. In order, the world's three largest grain producing countries in 2002 were China, the United States, and India

Figure 5.7 illustrates the success of using high-input monoculture farming to produce food and ward off-sharp rises in hunger, malnutrition, and food prices. Here are three pieces of good news about food production. First, world grain production almost tripled (Figure 5.7 left), and per capita grain production rose by about 36% (Figure 5.7, right) between 950 and 1990.

Second, the relative per capita food production in most parts of world increased between 1961 and 2002 (Figure 5.8). To maintain good health and resist disease, we need fairly large amounts of macronutrients such as protein, carbohydrates, and fats) and Smaller amounts of micronutrients consisting of various vitamins (such, as A, C, and E) and minerals (such as iron, Iodine, and calcium). People who cannot grow or buy enough food to meet their basic energy needs suffer from under nutrition. Chronically undernourished children are likely to suffer from mental retardation and stunted growth. They also tend to be much more susceptible to infectious diseases (such as measles and diarrhea); which kill one child in four in developing countries.

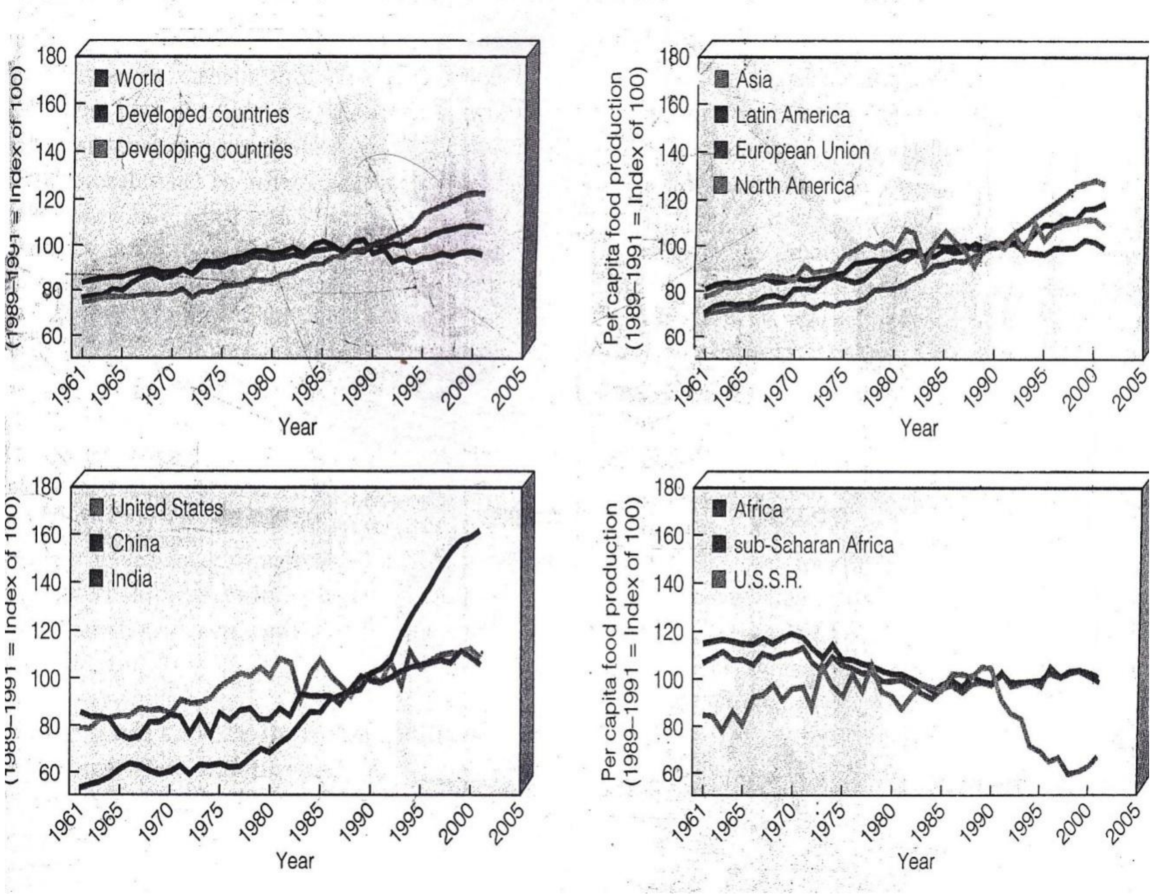


Figure 5.8: Good and Bad News; Indexes showing relative percapita food production, 1961-2001, using 1989-1991 as the index base

Many of the world's poor can afford to live only on a low-protein, high-carbohydrate diet consisting only of grains such as wheat, rice or corn. Many of them suffer from malnutrition:

deficiencies of protein and other key nutrients. Many of the world's desperately poor people, especially children suffer from both chronic under nutrition and chronic malnutrition.

Chronically undernourished and malnourished people are disease prone and adults are too weak to work productively or think clearly. As a result, their children also tend to be underfed, malnourished, and susceptible to disease. If these children survive to adulthood, many are locked in a malnutrition and poverty cycle (Figure 5.9) that can continue for generations.

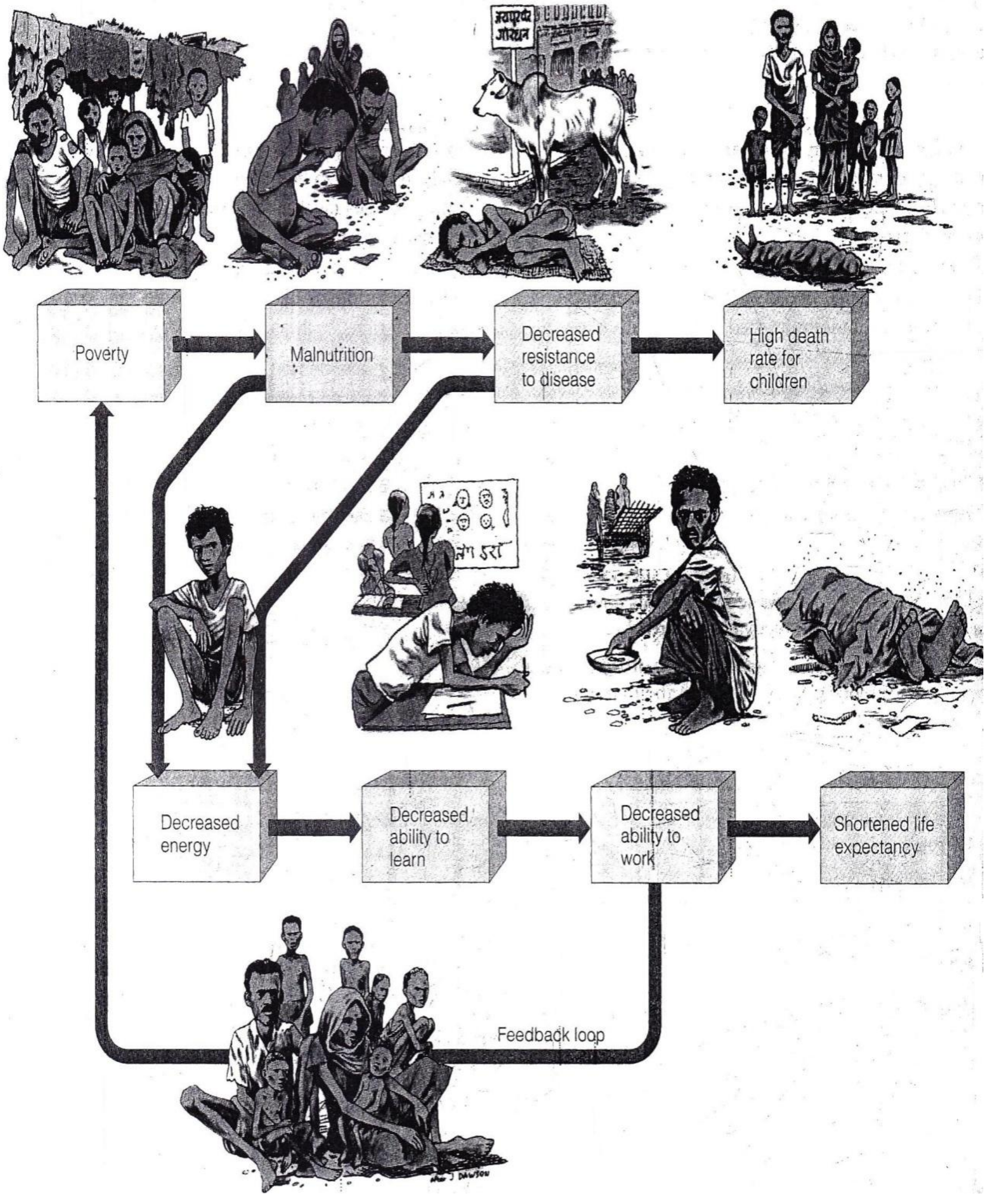


Figure 5.9: Interactions between poverty, malnutrition and disease can form a tragic cycle that can perpetuate such conditions in succeeding generations of families

How Serious Are Undernutrition and Malnutrition? Here is some good news. According to the UN Food and Agriculture Organization (FAO), the average daily food intake in calories per person in the world and in developing countries rose sharply between 1961 and 2000, and is projected to continue rising through 2030. In addition, the estimated number of chronically undernourished or malnourished people fell from 918 million in 1970 to 815 million in 2001. About 774 million of these people were in developing countries (especially in Asia and Africa, and 41 million were in developed countries.

However, according to the FAO, World Bank, and WHO there is also some bud news. About one of every six people in/developing countries (including about one of every three children below age 5) is chronically undernourished or malnourished. The 1996 World Food Summit goal of cutting the number of undernourished and malnourished people to 400 million by 2015 will probably not be achieved before 2030—15 years later than the original goal.

Finally, according to 2002 data from the WHO and Food and Agriculture Organization, in 2001 at least 9 million people—6 million of them children u rider age 5 died prematurely from a combination of several causes. They were undernutrition and malnutrition; infectious diseases caused by drinking contaminated water, and increased susceptibility to normally nonfatal infectious diseases (such as measles and diarrhea because of their weakened condition from malnutrition. This means that each day at least 25,000 people die prematurely because of malnutrition and infectious disease caused mostly by poverty.

Solutious: What Can We Do to Save Children from Malnutrition and Disease?

According to the WHO, seven of ten deaths of children under age 5 in developing countries can be attributed to one or a combination of five main causes: malnutrition, pneumonia, diarrhea, measles, and malaria. Some good news is that studies by the Unite Nations Children's Fund (UNICEF) indicate that one half to two-thirds of childhood deaths from nutrition annual cost of only $ 5-10 per child, or only 10-19 per week. This life-saving program would involve the following measures:

- Immunizing children against childhood diseases such as measles
- Encouraging breast-feeding (except for mothers with AIDS)
- Preventing dehydration from diarrhea by giving infants a mixture of sugar and salt in a glass of water
- Preventing blindness by giving children a vitamin A capsule twice a year at a cost of about 750 per child or fortifying common foods with vitamin A and other micro nutrients at a cost of about 100 per child annually

- Providing family planning services to help mother's space births at least 2 years apart
- Increasing education for women, with emphasis on nutrition, drinking water sterilization, and child care.

How Serious Are Micronutrient Deficiencies?

According to the WHO, about 2 billion people—about one out of three people—suffer from a deficiency of one or more vitamins and minerals. The most widespread micronutrient deficiencies in developing countries involve vitamin A, iron, and iodine. According to the WHO, 120-140 million children in developing- countries are deficient in vitamin A (found in dairy products and green and yellow vegetables). This puts them at risk for blindness and premature death because even mild vitamin A deficiency reduces children's resistance to; infectious diseases such as diarrhea and measles. Globally about 250,000 children under age 6 go blind each year from a lack of vitamin A and up to 80% of them die within a year.

Other nutritional deficiency diseases are caused by the lack of minerals. Too little iron (a component of hemoglobin that transports oxygen in the blood) causes anemia. Iron is found in legumes, green leafy vegetables, eggs, and meat. Iron deficiency causes fatigue, makes infection more likely, and increases a woman's chances of dying in childbirth. It also increases an infant's chances of dying of infection during its first year of life and cripples efforts to improve primary school education because developing brains need adequate iron to learn. According to a 1999 survey; by the WHO, one of every three people, mostly women and children in tropical developing countries, suffers from iron deficiency. The most severe problem is in India, where more than 80% of all pregnant women are anemic. Elemental iodine is essential for proper functioning of the thyroid gland, which produces a hormone that controls the body's rate of metabolism; Iodine is found in seafood and crops grown in iodine-rich soils. Chronic lack of iodine can cause stunted growth, mental retardation, and goiter (an abnormal enlargement of the thyroid gland that can lead to deafness).

Some good news is that WHO and UNICEF programs to get countries to add iodine, to salt slashed the percentage of the world's people with iodine deficiency from 29% to 12% between 1994 and 1999. Some bad news is that this still leaves at least 740 million people in developing countries with too little iodine in their diet. According to estimates by the UN Educational, Scientific, and Cultural Organization (UNESCO), about 26 million children suffer brain damage each year from lack of iodine and 600 million people—mostly in South and Southeast Asia—suffer from goiter. The FAO estimates that spending$24biHion a year would be enough to end hunger and malnutrition within 10-15 years. According to :the FAO, this expenditure would yield at least $120 billion per year in benefits as a result of longer, healthier, and more productive lives for several hundred million people freed from malnutrition and poverty.

How Serious is Over nutrition? Overnutrition occurs when food energy intake exceeds energy use and causes excess body fat. Overnourished people are classified as overweight if they are roughly 4.5-14 kilograms: (10-30 pounds) over a healthy body weight and obese if they are more than 14- kilograms (30 pounds) over a healthy weight. Too many calories, too little exercise, or both can cause overnutrition.

People who are underfed and underweight and those who are overfed and overweight face similar health problems: lower life expectancy, greater susceptibility to disease and illness, and lower productivity and life quality. Overnutrition is the second leading cause of preventable deaths after smoking, mostly from heart disease, cancer, stroke, and diabetes. An estimated 300,000 Americans die prematurely each year as a result of being overweight or obese—the second greatest health risk after smoking. This death toll is roughly equivalent to two fully loaded jumbo (400-passenger) jets crashing accidentally every day with no survivors.

A study of thousands of Chinese villagers indicates that the healthiest diet for humans is largely vegetarian, with only 10-15% of calories coming from fat. This is in contrast to the typical meat-based diet, in which 40% of the calories come from fat. About 14% or one out of seven adults in developed countries suffers from overnutrition. The situation is much worse in the United States. According to the 2002 National Health Examination Survey, about 65% of American adults (ages 20-74) were overweight or obese in 2000—up from 45% in 1961 and 47% in 1981. This is the highest overnutrition rate of any developed country. The $37 billion Americans spend each year trying to lose weight is 1.5 times more than the $24 billion per year needed to eliminate undernutrition and malnutrition in the world.

Do We Produce Enough Food to Feed the World's People? The good news is that according to the FAO we produce more than enough food to meet the basic nutritional needs of every person on the earth today. If distributed equally, the grain currently produced worldwide is enough to give everyone a meatless subsistence diet. According to food analysts, there should also be more food for more people in the future.

The bad news for the one out of eight people not getting enough to eat is that food is not distributed equally among the world's people because of differences in soil, climate, political and economic power and average per capita income throughout the world. Most agricultural experts agree that % principal cause of hunger and malnutrition is and will continue to be poverty, which prevents poor people from growing, or buying enough food regardless of how much is available, For example, according to the United Nations, in the 1990s nearly 80% of all chronically undernourished and malnourished children lived in .countries with food surpluses.

What Are the Environmental Effects of Producing Food? Agriculture has significant harmful effects on air, soil, water, and biodiversity. Some analysts believe these harmful environmental effects can be overcome and will not limit future food production.

Other analysts disagree. For example, according to Norman Myers, the future ability to produce more food will be limited by a combination of environmental factors. They include soil erosion, decertification, salinization and waterlogging of irrigated land, Water deficits and droughts, loss of wild species that provide the genetic resources for improved forms of foods, and the effects of global warming in some parts of the world. According to a 2002 study by the UN Department for Economic and Social Affairs,, close to 30% of the world's (cropland has, been degraded by soil erosion, salinity, and chemical pollution/and 17% has been seriously degraded.

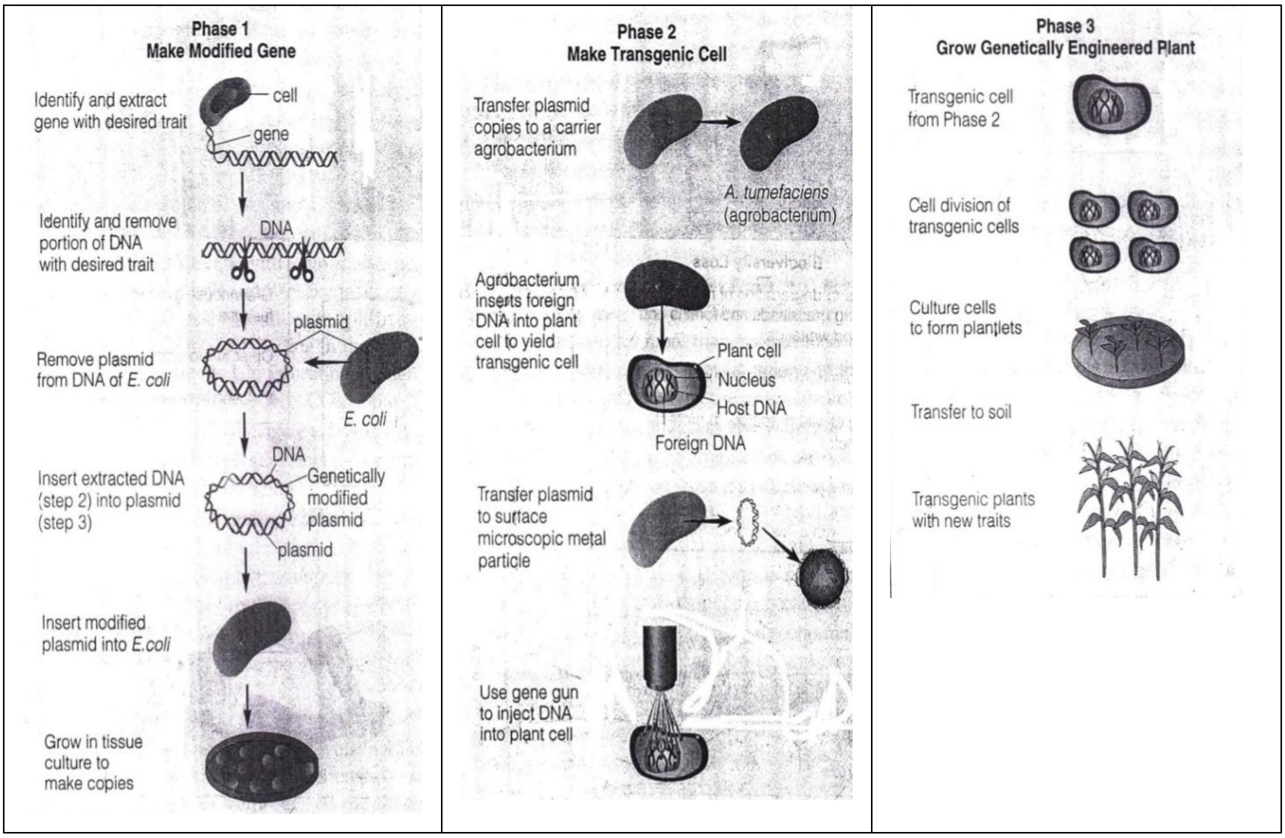


Figure 5.10: Steps in genetically modifying a plant

Increasing world crop production

Is Increasing Crop Yields the Answer? Agricultural experts expect most future increases in food yields per hectare to result from improved crossbred strains of plants and from expansion of green revolution technology to new parts of the world. Traditional crossbreeding is a slow process that typically takes 15 years or more to produce a commercially valuable new variety. Also, it can combine traits only from species that are close to one another genetically. In addition, crossbred varieties are useful for only about 5-10 years before pests and diseases reduce their effectiveness.

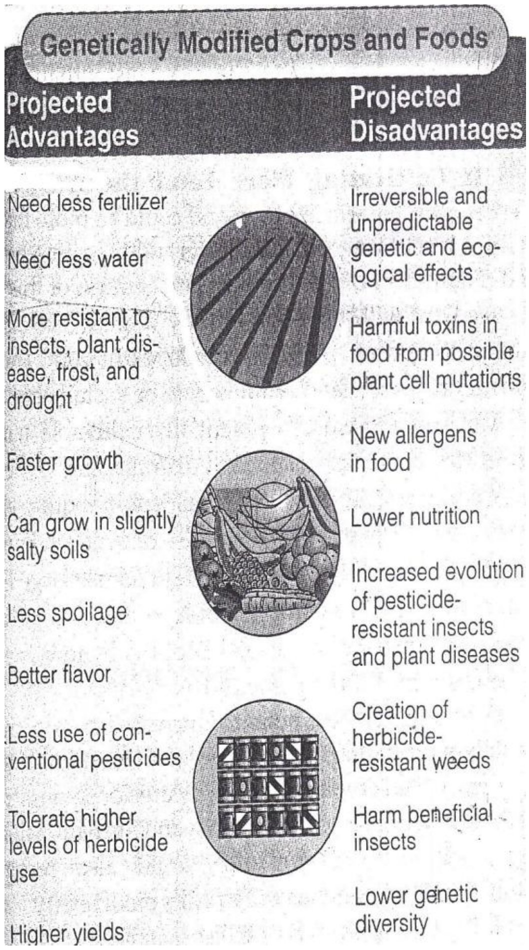


Figure 5.11: Projected advantages and disadvantages of genetically modified crops and foods

Is Genetic Engineering the Answer? Scientists are working to create new green revolutions actually gene revolutions—by using genetic engineering and other forms of biotechnology to develop genetically improved strains of crops. Genetic engineering, gene splicing, of food crops is the insertion of an alien gene into a commercially valuable plant (or animal) give it new beneficial genetic traits. Such organisms are called genetically modified organisms (GMOs)

Compared to traditional crossbreeding, gene splicing takes about half as; much time, to develop a new crop or animal variety, cuts costs, and allows the insertion of genes from almost arty other organism into crop or animal cells. Figure-5.10 outlines the steps involved in developing a genetically modified, or transgenic, plant. Scientists are also using advanced tissue culture techniques to produce; only, the desired parts of a plant such as its-oils or fruits.

Ready or not, the world is entering the age of genetic engineering. The United States is the world's largest producer of genetically modified crops. For example, the U.S. Departmental Agriculture (USDA) estimated that 75% of soybeans, 71, % of cotton, and 34% of corn planted by U.S. farmers in 2001 were GMOs. Nearly two thirds of the food products on U.S. supermarket shelves contain genetically engineered crops and the proportion is increasing rapidly. However, there is growing controversy over the use of genetically modified food (GMF). Such food is seen as a potentially sustainable way to solve world food items by its producers and investors and called potentially dangerous "Frankenfood" by its critics. Figure 5.11 summarizes the projected advantages and disvantages of this new technology.

Critics recognize the potential benefits of genetically modified crops. However, they warn we know far too little about the potential harm to human health and ecosystems from widespread use of such crops. In addition, genetically modified organisms cannot be recalled if they pause harmful genetic and ecological effects. They cal1 for more controlled field experiments, more research and long-term safety testing to better understand the risks, and stricter regulation of this new and rapidly growing technology. Many analysts and consumer advocates believe governments should require mandatory labeling of genetically modified foods. This would provide consumers with information to help them make more informed choices about the foods they buy. Such labeling is required in Japan, Europe/South Korea, Canada, Australia/and New Zealand and is favored by 81% of Americans polled in 1999.

There is also concern about the use of genetic engineering to produce bioengineered pathogens (mostly bacteria and viruses) that could be used to devastate a country's crops and livestock animals during warfare or as an act of terrorism. According to a 2002 report by the National Academy of Sciences, conventional and bioengineered pathogens for harming crops or livestock are widely available and fairly easy to produce and pose a major threat to U.S. agriculture. According to the study, abioterrorism attack on U.S. agriculture is highly unlikely to result in famine or malnutrition, but it could harm people, disrupt the economy, and cause widespread public confusion and fear.

Can We Continue Expanding the Green Revolution? Many analysts believe it is possible to produce enough food to feed the 9.3 billion people projected by 2050. This would be accomplished through new advances in gene-splicing technology and by spreading the use of new and existing high-yield green revolution techniques throughout most of the world.

In 2002, for example, the International Rice Institute announced it was working on two new varieties of genetically modified 'rice. One, called aerobic rice, could be grown with much less water than conventional rice strains. The other, called: dream rice, is supposed to provide more iron, vitamin; A, and lysine than conventional rice varieties. If dream rice lives up to its potential, it will be especially helpful in reducing chronic malnutrition among the poor. In addition, in 2002 scientists reported developing a form of genetically engineered rice that can withstand drought, salt water, and cold temperatures by borrowing a gene from Escherichia coli (E. coli) bacteria.

Other analysts point to several factors that have limited the success of the green and gene revolutions to date and may continue to do so. First, without huge amounts of fertilizer and water, most green revolution crop varieties produce yields that are no higher (and are Sometimes lower) than those from traditional straits. This is why the second green revolution has not spread to many arid and semiarid areas such as much of Africa and Australia.

Second, green revolution and; genetically engineered crop strains and their high inputs of water, fertilizer, and pesticides cost too much for most subsistence farmers in developing countries.

Third, grain yields per hectare in many parts of the world but at a much slower rate. For example, grain yields rose about 2.1% a year between 1950 and 1990 but dropped to 1.1% per year between 1990 and 2000.

Fourth, crop yields in some areas may start dropping as soil erodes and loses fertility, irrigated soil becomes salty and waterlogged, underground and surface water supplies become depleted and polluted with pesticides and nitrates from fertilizers, and populations of rapidly breeding pests develop genetic immunity to widely used pesticides. We do not know; how close we are to such environmental limits in various parts of the world.'

Fifth, increased loss of biodiversity can limit the genetic raw material needed for future green and gene revolutions.

Finally, according; to Indian economist Vaidana Shiva, overall gains in crop yields from new green and gene revolution varieties may be much lower- than claimed. The yields are based on comparisons between the output per hectare of old and new monoculture varieties rather than between the even higher yields per hectare for polyculture cropping systems and the new monoculture varieties that often replace polyculture crops.

Will People Try New Fpods? Some analysts recommend greatly increased cultivation of less widely known plants to supplement or replace such staples as wheat, rice, and corn. One of many possibilities is the winged bean, a protein-rich legume now common only in New Guinea and Southeast Asia. This fast-growing plant is a good source of protein and has so many edible parts it has been called a supermarket on a stalk. It also needs little fertilizer because of nitrogen-fixing nodules in its roots.

Insects called microlivestock are also important potential sources of protein, vitamins, and minerals in many parts of the; world. There are about 1,500 edible insect species. Some are important food items in many parts of the world. Examples include black ant larvae (served in tacos in Mexico), giant water bugs (crushed into vegetable dip in Thailand), Mopani or emperor moth caterpillars (eaten in South Africa), cockroaches (eaten by Kalahari desert dwellers), lightly toasted butterflies (a favorite food in Bali), and fried ants (sold on the streets of Bogota, Colombia). Most of these insects are 58-78% protein by weight—three, to four times as protein rich as beef, fish, or eggs. Two problems are getting farmers to take the financial risk of cultivating new types of food crops and convincing consumers to try new foods. Some plant scientists believe we should rely more on polycultures of perennial crops, which are; better adapted to regional soil and climate conditions than most annual crops. Using perennials would also eliminate the need to till soil and replant seeds each year, greatly reduce energy use, save water, and reduce soil erosion and Water pollution from eroded sediment. However, large seed companies that makes their money selling farmers seeds each year for annual crops generally oppose this idea.

Is Irrigating More Land the Answer? About 40% of the world's food production comes from the 18% of the world's cropland that is irrigated. Irrigated land produces about 70% of the grain harvest in China, 50% in India, and 15% in the United States.

Some good news is that between 1950 and 2002, the world's irrigated area tripled, with most of the growth occurring from 1950 to 1978. Some bad news is that since 1978, the amount of irrigated land per person has been falling and is projected to fall much more between 2000 and 2050. One reason for this downward trend is that the world population has grown faster than irrigated agriculture since 1978. Other factors are aquifer depletion, inefficient use of irrigation water soil salinization on irrigated crop land, and disruption of water supplies in some food growing areas from global warming. In addition, the majority of the world's farmers do not have enough money to irrigate their crops. According to analysts, there are three key methods for using water more sustainably in crop production. One is to increase irrigation efficiency. Another is to shift to crops that need less water. For example, we could depend less on water-thirsty rice and sugarcane and more on wheat and sorghum. The third is to withdraw water from aquifers no faster than they are replenished.

Is Cultivating More Land the Answer?

Theoretically, the world's cropland could be more than doubled by clearing tropical forests and irrigating arid land. The problem is that much of this is marginal land with poor soil fertility, steep slopes, or both. Thus cultivation of such land is unlikely to be sustainable. Much of the world's potentially cultivable land lies in dry areas, especially in Australia and Africa. Large-scale irrigation in these areas would require expensive dam projects with a mixture of beneficial and harmful impacts and use large inputs of fossil fuel to pump water long distance. This could also deplete groundwater supplies by removing water faster than it is replenished.

Furthermore, these potential increases in cropland would not offset the projected loss of-almost 30% of today's cultivated cropland caused by erosion, overgrazing, water logging, salinization, and urbanization. Such expansion in cropland would also reduce wildlife habitats and thus the world's biodiversity. Thus many analysts believe that significant expansion of cropland is unlikely over the next few decades. For example, the International Food Policy Institute and FAO estimate that 80% of the projected increase in food production between 1993 and 2020 will come from increased yields per hectare and only 20% from expansion on of cropland.

Can We Grow More Food in Urban Areas?

Currently, about 800 million urban gardens provide about 15% of the world's food. Food experts believe that people in urban areas could live more sustainably and save money by growing more of the food. Such food could be grown in empty lots, in backyards, on rooftops and balconies, and by raising fish in tanks sewage lagoons. A study by the UN Center for human Settlements estimated that up to 50% of f the total area in many cities in developing countries is vacant public land that could be used to produce food.

Producing more meat

What Are Rangeland and Pasture? About 40% of the earth's ice-free land is rangeland that is too dry, too steeply sloped, or too infertile to grow crops. This type of land supplies forage or vegetation for grazing (grass eating) and browsing (shrub-eating) animals. About 5 billion cattle, sheep, and goats graze on about 42% of the world's rangeland. Much of the rest is too dry, cold, or remote from population centers to support large numbers of livestock. About 29% of the total prairie in the arid and semiarid western half of the country. Livestock also graze in pastures: managed grasslands or enclosed meadows usually planted with domesticated grasses or other forage.

Most rangeland grasses have deep and complex root systems (Figure 9-18, top right) that help anchor the plants. These roots also extract underground water so plants can withstand drought, and store nutrients so plants can grow again after a drought or fire. Blades of rangeland grass grow from the base, not the tip. Thus, as long as only its upper half—called its metabolic reserve—is eaten and its lower half remains, rangeland grass is a renewable resource that can be grazed again and again. The exposed metabolic reserve of a grass plant is where photosynthesis takes place to provide food for the deep roots of rangeland grasses. If all or most of the lower half of the plant is eaten, the plant is weakened and can die.

How Is Meat Produced, and What Are Its Environmental Consequences? Meat and meat products are good sources of high-quality protein. Between 1950 and 2002, world meat production increased more than fivefold, and per capita meat production more than doubled. Globally, animal; products provide about 15% of the energy and 30% of the protein in the human diet.

About 80% of the world's cattle, sheep, and goats are raised on rangeland by open grazing or nomadic herding (Figure 5.2). Some analysts expect most future increases in meat production to come from densely populated feedlots, where animals are fattened for slaughter by feeding on grain grown on cropland or meal produced from fish. Feedlots account for about 43% of the world's beef production and more than half of the world's poultry and pork. The good news is that this industrialized approach increases meat productivity. The bad news is that it also has a number of harmful environmental effects. It creates foul odors, and causes water pollution when lagoons storing animal wastes collapse or are flooded. Nitrates from animal wastes can also contaminate drinking water wells.

Meat production also increases pressure on the world's grain supply because livestock and fish raised for food consume about 37% of the world's grain production (70% in the United States). In addition, meat production requires increased inputs of fossil fuel (Figure 5.6). Producing meat can also i endanger wildlife species. According to a 2002 report by the National Public Lands Grazing: Campaign, livestock grazing has contributed to population declines of 22% of the country's threatened and endangered species. Finally meat production uses more than half of the water withdrawn worldwide from rivers and aquifers each year.' Most of this water is used to irrigate crops fed to livestock and wash away manure from crowded livestock pens and feedlots.

How Can We Produce Meat More Sustainably?

Livestock and fish vary widely in the efficiency with which they convert grain into animal protein (Figure 5.12). A more sustainable form of meat production would involve shifting from less grain-efficient forms of animal protein, such as beef or pork, to more grain-efficient ones, such as poultry or farmed fish. Some environmentalists have called for reducing livestock production (especially cattle) to decrease its environmental effects and to feed more people. This would decrease the environmental impact of livestock production, but it would not free up much land or grain to feed more; of the world's hungry people.

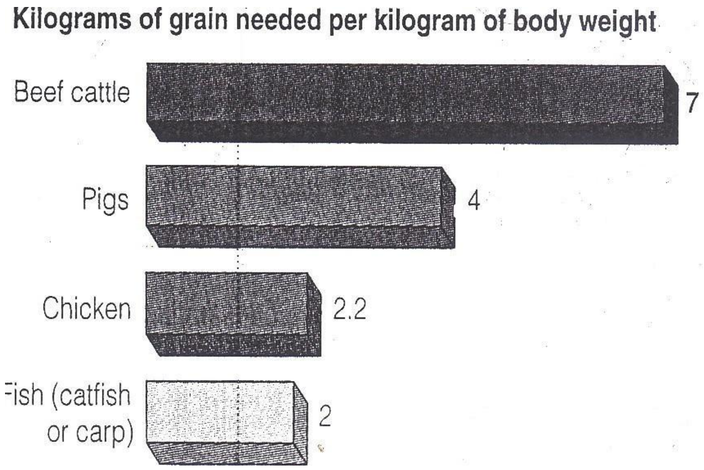


Figure 5.12: Efficiency of converting grain into animal protein. Data in Kilograms of grain per kilogram of body weight added

Cattle and sheep that graze on rangeland use a resource (grass) that humans cannot eat, and most of this land is not suitable for growing crops. Moreover, because of poverty, insufficient economic aid, and the nature of global economic and food distribution systems, very little if any additional grain grown on land used to raise livestock ;or livestock feed would reach the world's hungry-people.

What Are the Effects of Overgrazing and under grazing? Overgrazing can limit livestock production. Overgrazing occurs when too many animals graze for too long and exceed the carrying capacity of a grassland area. Excessive numbers of domestic livestock feeding for too long in a particular area causes most overgrazing. Such overgrazing lowers the net primary productivity of grassland vegetation and reduces grass cover. It also and exposes the soil to erosion by water and; wind, compacts the soil (which diminishes its capacity to hold water), and is a major cause of desertification.

Some grassland can suffer from undergrazing where absence of grazing for long periods (at least 5 years) can reduce the net primary productivity of grassland vegetation and grass cover. Moderate grazing of such areas removes accumulations of standing dead material and stimulates new biomass production

What Is the Condition of the World's Range lands? *Range condition* usually is classified as excellent (containing more than 75% of its potential forage production), good (51-75%), fair (26-50%), or poor (0-25%). Limited data from surveys in various countries indicate that overgrazing by livestock has caused as much as 20% of the world's rangeland to lose productivity, mostly by desertification (Figure 9-22).

Most of the rangeland in the United States is in the West. About 60% is privately owned and the rest is public land managed by the Bureau of Land management (BLM) and the U.S.

Forest Service. Only about 2% of [the 120 million cattle and 10% of the 20 million sheep raised in the United States graze on public rangelands. According to a 2000 survey by the Bureau of Land Management, about 64% of the nonarctic U.S. public rangeland it managed was in unsatisfactory (fair or poor) condition, compared with 84% in 1936. This rep resents a great improvement/but there is still a long way to go. According to some wildlife and rangeland experts, estimates of rangeland condition do not take into account severe damage to heavily grazed thin strips of lush vegetation along streams called riparian zones. These ecologically important areas help keep streams from drying out during droughts by storing and releasing water slowly from spring runoff and summer storms. They also provide habitats, food, water, and shade for wildlife in the arid and semiarid western lands.

Studies indicate that 65-75% of the wildlife in the western United States, totally depends on riparian habitats. According to a 1999 study in the Journal of Soil and water Conservation, livestock grazing has damaged approximately 80% of steam and riparian ecosystems in the United-States. Some good news is that we can restore riparian areas by using fencing to restrict access to degraded areas and developing off-stream-watering sites for livestock. Sometimes protected areas can recover in a few years.

How Can Rangelands Be Managed More Sustainably to Produce More Meat?

The primary goal of sustainable rangeland management is to maximize livestock productivity without overgrazing or undergrazing rangeland vegetation. There are two major ways to do this. One is to control the number, types and distribution of livestock grazing on land. The other is to restore and improve degraded rangeland. The most widely used method for more sustainable rangeland management is to control the number of grazing animals and the duration of their grazing in a given area so .the carrying capacity of the area is not exceeded. However, determining the carrying capacity of a range site is difficult and costly In addition, carrying capacity varies with factors such as drought, soil type, and invasions by new plant or animal species, kinds of grazing animals, and intensity of grazing.

Livestock tend to aggregate around natural water sources and stock ponds. As a result, areas around water sources tend to be overgrazed and other areas can be undergrazed. Managers can use several strategies to prevent this and help promote more uniform use of rangeland. Damaged rangeland and riparian zones can be fenced off and livestock can be moved from one grazing area to another. Ranchers can also provide supplemental feed at selected sites and locate water holes and tanks and salt blocks in strategic places.

A more expensive and less widely used method of rangeland management involves suppressing the growth of unwanted plants by herbicide spraying, mechanical removal, or controlled burning. A cheaper way to discourage unwanted vegetation is controlled, short-term trampling by large numbers of livestock.

Catching and Raising More Fish and Shellfish

How Are Fish and Shellfish Harvested?

The world's third major food-producing system consists of fisheries: concentrations of particular aquatic species suitable for commercial harvesting in a: given ocean area or inland body of water. Some commercially important marine species of fish and shellfish are shown in Figure 5.13. Fish and shellfish supply about 7% of the global food supply and are the primary source of animal protein for about 1 billion people, mostly in developing countries.

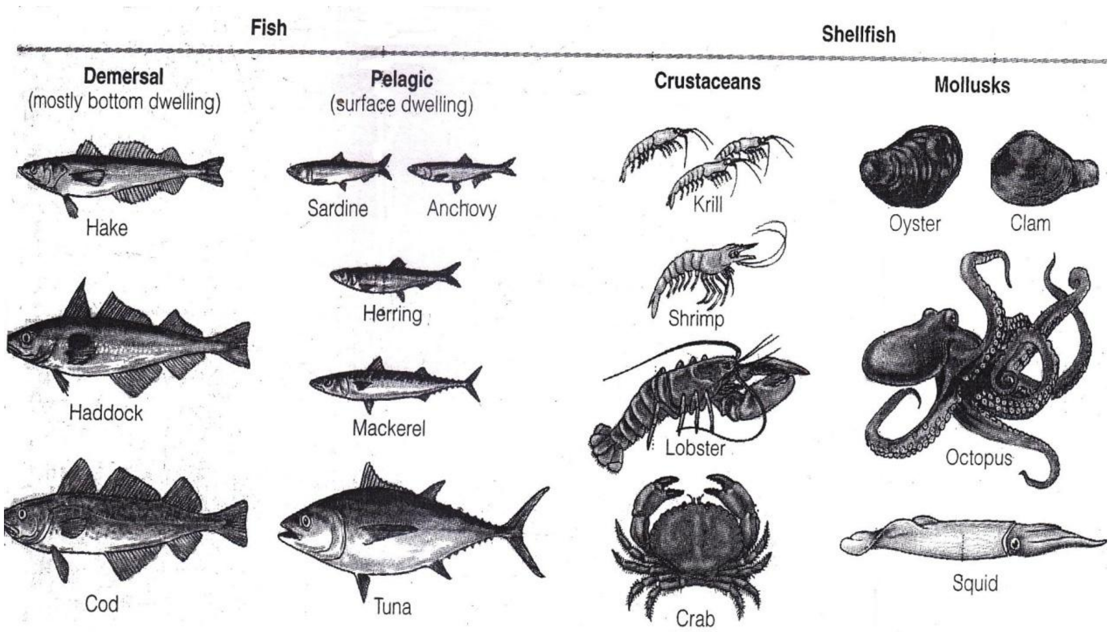


Figure 5.13: Some major types commercially harvested marine fish and Shelfish

The world's commercial fishing industry is dominated by industrial fishing fleets using satellite positioning equipment, sonar, huge nets, spotter planes, and factory ships that can process and freeze their catches. The rest of the annual catch comes from using aquaculture to raise marine and freshwater fish in ponds and underwater cages (33%) and from inland freshwater fishing from, lakes, rivers, reservoirs, and ponds (12%). About one-third of the world fish harvest (mostly small surface-dwelling species such as anchovy, herring, and menhaden) is used as animal feed, fish meal, and oils.

Can We Harvest More Fish and Shellfish?

The good news is that between 1950 and 2000, the annual commercial fish catch (marine plus freshwater harvest) increased almost fivefold (Figure 5.14, left), and the per capita seafood catch more than doubled figure 5.14, right). The bad news is that the commercial fish catch has dropped and leveled off since 1982 (Figure 5.14). Also, the per capita commercial fish catch has been falling since 1992 (Figure 5.14, right) and may continue to decline because of overfishing, pollution habitat loss, and population growth.

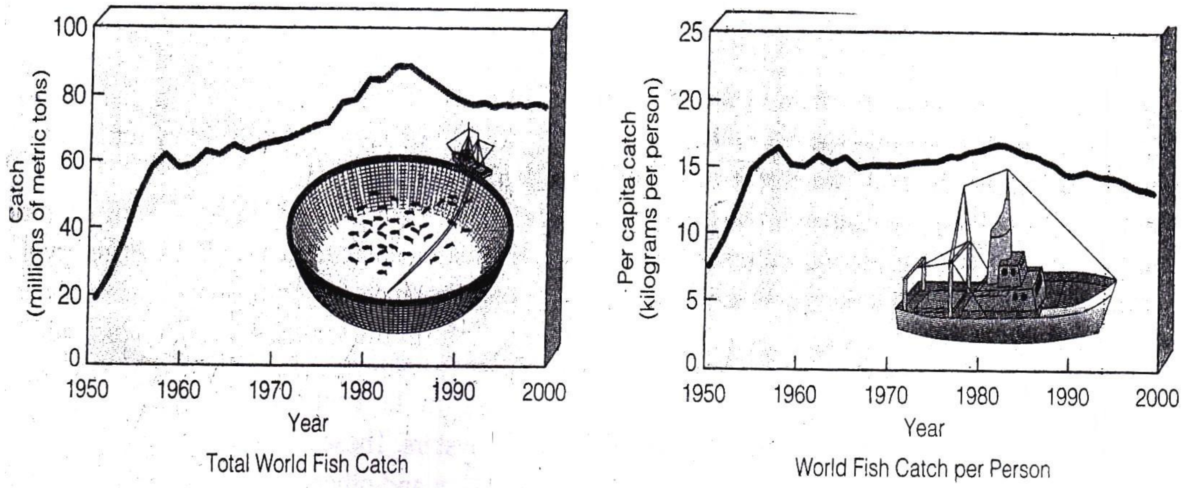


Figure 514: World fish catch (left) and world fisrjcatch per person (right), 1950-2000, Worldwide per capita fish catch did not rise much between 1§68 and 1989 and has dropped since then. The total catch and^per capita catches since 1990 are piobably about 10% lower than shown here because of the discovery in 2002 that since 1990 China had apparently been inflating its fish catches

Connections: How Are Overfishing and Habitat Degradation Affecting Fish Harvests?

Fish are renewable resources as long as the annual harvest leaves enough breeding stock to renew the species for the next year. Ideally, an annual sustainable yield the size of the annual catch that could be harvested indefinitely without a decline in the population of a species— should be: established for each species to avoid depleting the stock. However, determining sustainable yields is difficult because it is hard to estimate mobile aquatic populations. Also, sustainable yields shift from year to year because of changes in climate, pollution, and other factors. In addition, sustainably harvesting the entire annual surplus of one species may severely reduce the population of other species that rely on it for food.

Overfishing is the taking of so many fish that too little breeding stock is left to maintain numbers; that is, overfishing is a harvest of a species that exceeds its sustainable yield. Prolonged overfishing leads to commercial extinction, when the population of a species declines to the point at which it is no longer profitable to hunt for them. Fishing fleets then move to a new species or a new region, hoping that the overfished species will eventually recover.

High levels of by catch (the non target fish that are caught in nets and then thrown back into the sea) also deplete fisheries. Nearly one fourth of the annual global fish catch is by catch that depletes marine biodiversity and does not provide food for people. Here are several pieces of bad news about the world's fish stocks. First, a 2001 report by the UN Food and Agriculture Organization found that about75% of the world's 200 commercially valuable marine fish species are either overfished or fished to their estimated sustainable yield. The primary cause of this depletion of fish stocks is too many fishing boats pursuing too few fish another example of the tragedy of the commons. According to the Ocean Conservancy, we are spending the principal of our marine fish resources rather than living off the interest they provide.

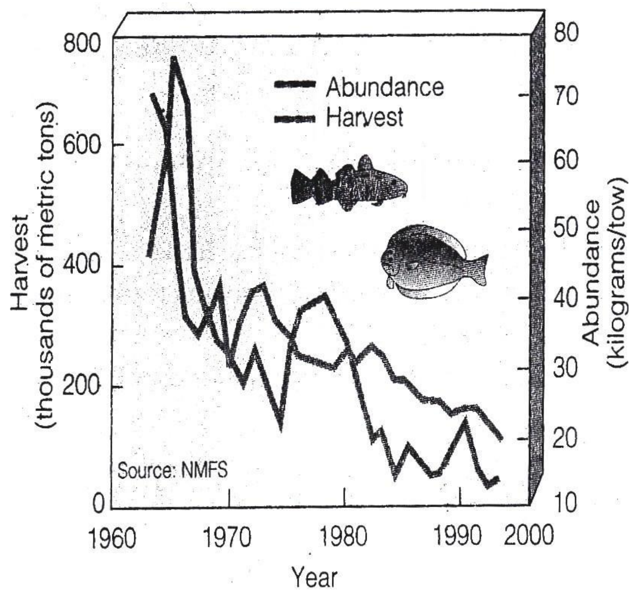


Figure 5.15: The harvest of groundfishes (yellowtail flounder, haddock, and cod) in the Georges Bank off the coast of New England in the North Atlantic, once one of the world's most productive fishing grounds, has declined sharply since 1965. Stocks dropped to such low levels that since; December 1994 the National Marine Fisheries Services has banned fishing of these species in the Georges Bank

Second, studies by the U.S. National Fish and Wildlife Foundation show that 14 major commercial fish species in U.S. waters (accounting for one-fifth of .the world's annual catch and half of all U.S. stocks) are severely depleted (Figure 5.15). Some good news is that since 1996 some 25 species are no longer over fished and 70 others continue to recover.

Third, degradation, destruction, and pollution of wetlands, estuaries, coral reefs, salt marshes, and mangroves threaten populations of fish and shellfish. Fourth, global warming that is projected over the next 50-100 years is a threat to the global fish catch. Warmer sea water can degrade or destroy highly productive coral reefs and enhance the harmful effects of habitat degradation and pollution on fish populations.

Finally, a 2002 analysis by the World Fish Center and the International Food Policy Institute warned that the world's growing population and overfishing mean that 1 billion people in developing countries will face shortages of fish, their most important source of protein, by 2020.

Should Governments Continue Subsidizing Fishing Fleets? Because of overfishing and the overcapacity of the fishing fleet, it costs the global fishing industry about $120 billion a year to catch $70 billion worth of fish. Government subsidies such as fuel tax exemptions, price controls, low-interest loans, and grants for fishing gear make Up most of the $50 billion annual deficit of the industry: Without such subsidies the world's fishing industry would be bankrupt and the number of fish caught would approach their sustainable yield.

Phasing out these subsidies would cause a loss of jobs for some fishers and fish processors in coastal' communities. But to fishery biologists the alternative is worse. Continuing to subsidize excess fishing allows fishers to keep their jobs a little longer while making/ less and less money until the fishery collapses. Then all jobs are gone, and fishing communities suffer even more—another example of the tragedy of the commons in action.

What Is Aquaculture? Aquaculture, in which fish and shellfish are raised for food, supplies about 33% of the world's Commercial fish harvest. Some good news is that aquaculture production increased fivefold between 1984 and 2001. Developing countries account for about 85% of the world's aquaculture production. China is the world leader in aquaculture (producing about 68% of the world's output), followed by India, Japan, and the United States.

There are two basic types of aquaculture. One is fish farming. It involves cultivating fish in a controlled environment (often a coastal or inland pond, lake, reservoir, or rice paddy) and harvesting them when they reach the desired size. The other is fish ranching. It involves holding anadromous species such as salmon (that live part of their lives in fresh water and part in salt water) in captivity for the first few years of their lives, usually infenced in areas or floating cages in coastal lagoons and estuaries. Then the fish are released, and adults are harvested when they return to spawn (Figure 5.16).

Species cultivated in developing countries (mostly in inland aquaculture ponds, lakes, reservoirs, and rice paddies) include carp (especially in China and India), catfish (in the United States), tilapia, milkfish, clams and oysters, These herbivorous species feed on phytoplankton and other aquatic plants and thus eat low on the food chain. In developed countries and some rapidly developing countries in Asia, aquaculture is used mostly to stock lakes and streams with game fish or to raise expensive fish and shellfish (such as oysters, catfish crayfish, rainbow trout, shrimp, and salmon). Most of these species are exported to Japan, Europe, and North America. Aquaculture now produces 90% of all oysters, 40% of all salmon (75% in the United

States), 50 % of internationally traded shrimp and prawns, and 65% of freshwater fish sold in the global market place. Many of these species are fed grain or fish meal.

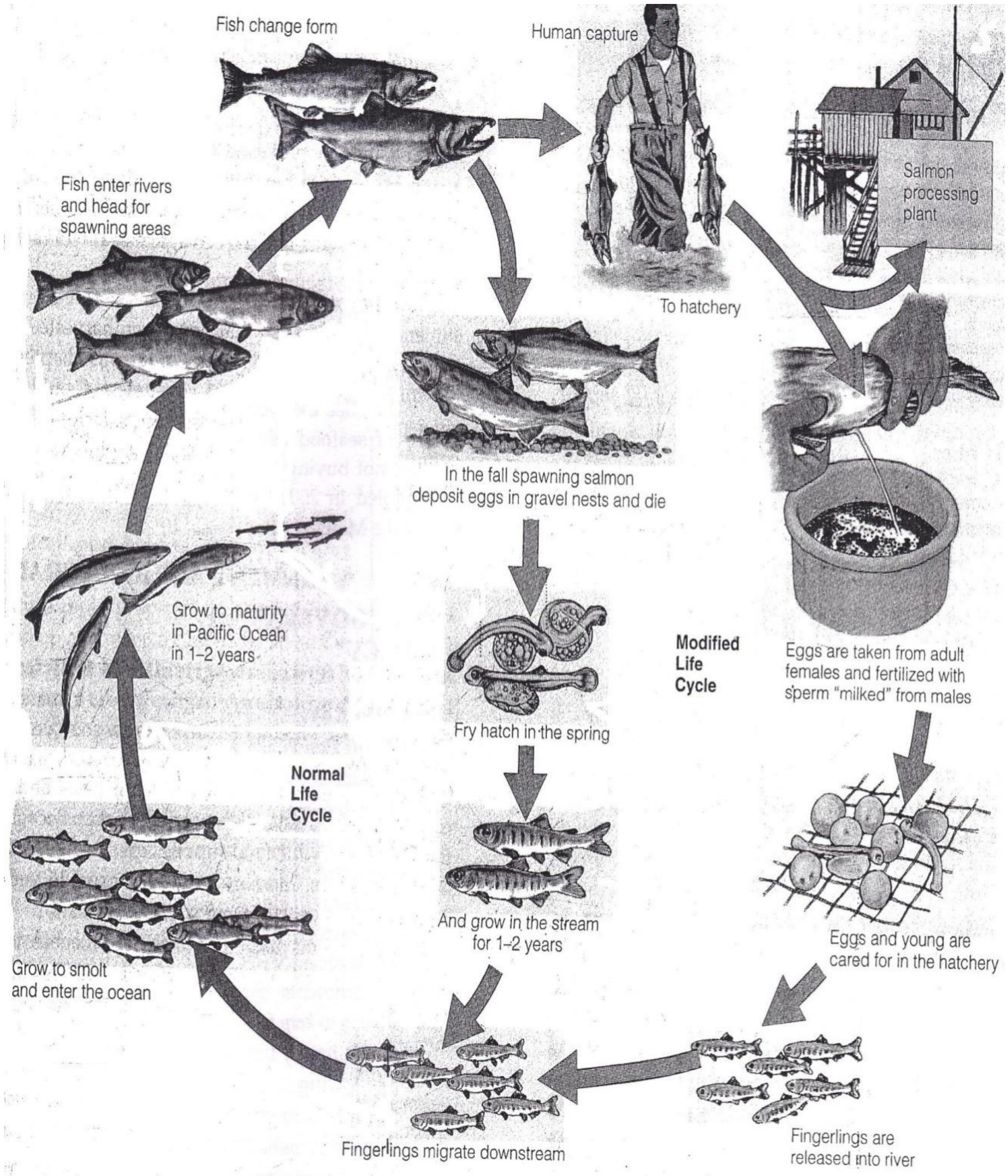


Figure 5.16: Normal life cycle of wild salmon (left) and human modified life cycle of hatchery raised salmon (right). Salmon spend part of their lives infresh water and part in salt water

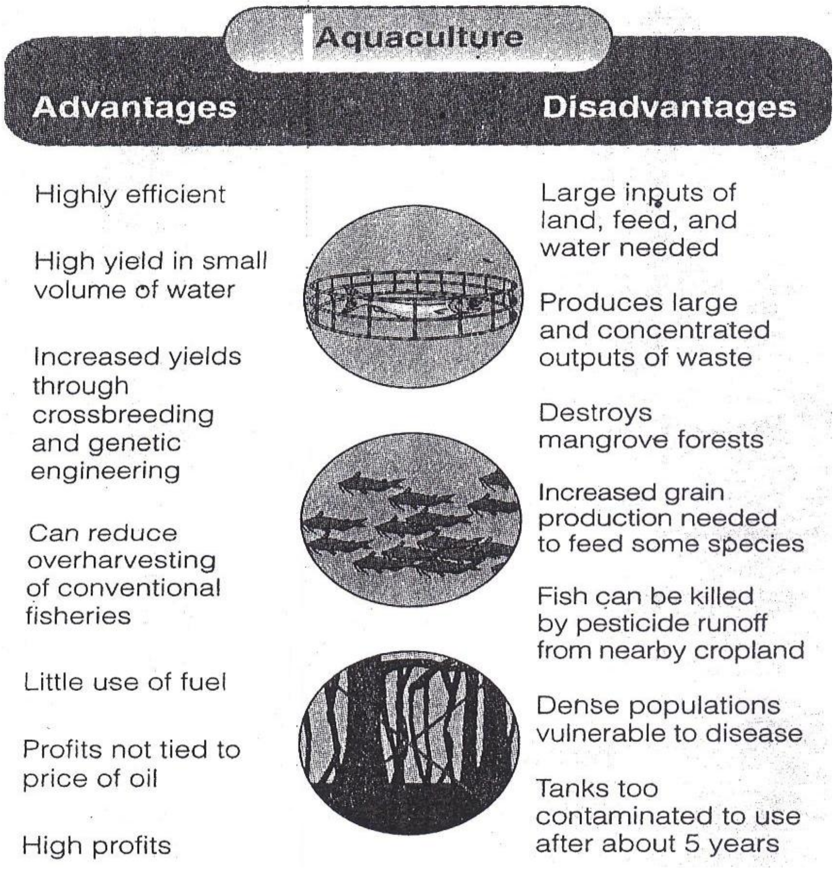


Figure 5.17: Advantages and Disadvantages of Aquaculture

Is Aquaculture the Answer? Figure 5.17 lists major advantages and disadvantages of aquaculture. Aquaculture may soon overtake cattle ranching as a source of animal protein. Future trends in cattle and aquaculture and in our diets are likely to depend on the efficiency with which cattle and fish convert grain to protein (figure 5.12).

Fish have a large cost advantage by requiring about 2 kilogram of grain to add 1 kilogram of live weight, whereas cattle require about 7 kilograms of grain to add 1 kilogram of live weight Water scarcity is another factor. If takes about l, 000 kilograms of water to produce 1 kilogram of grain whereas raising fish in an aquaculture pond takers much less water per kilo gram of fish. Some analysts project that freshwater and saltwater aquaculture production could provide 41% of the world's seafood by 2020. Other analysts warn that the harmful environmental effects of aquaculture (Figure 5.17) could limit future production.

But some aquaculture proponents point to new trends and research that may help decrease the harmful environmental effects of aquaculture. In his 2002 book Ecological Aquaculture, aquaculture expert Barry Costa-Pierce called for a number of changes in Aquaculture practices to reduce harmful environmental impacts and make them more sustainable. One reform is to reduce use of fishmeal as a feed so aquaculture programs do not consume more protein than they produce. Others are to reduce pollution by improving management of aquaculture wastes and eliminating the use of chemicals that harm human and ecosystem health. To increase efficiency, he calls for establishing better controls to reduce escape of aquaculture species into the wild and for recovery of escaped individuals. Finally, environmental labeling programs would certify that fish and shellfish were raised in a sustainable manner.

Other improvements have also been suggested. One is to restrict location of fish farms to reduce loss of mangrove: forests and other threatened coastal environments. Another suggestion is to increase production of herbivorous aquaculture fish species (such as carp, tilapia, and shellfish) that need little or no grain or fishmeal in their diets. However, even under the most optimistic projections, increasing both the wild catch and aquaculture will not increase world food supplies significantly. The reason is that currently fish and shellfish supply only about 1% of the calories and 7% of the protein in the human diet.

Solutions: How Can We Manage Fisheries More Sustainably? Analysts suggest a number of measures for managing global fisheries more sustainably and protecting marine biodiversity. One is to improve fishery regulations. This involves setting and enforcing fishery quotas well below their estimated maximum sustained yields, requiring selective gear that avoids catching unwanted or undersized fish, and improving monitoring and enforcement of fishing regulations.

A second method is to use economic approaches. One is to sharply reduce or eliminate government fishing subsidies. Another is to impose fees for harvesting fish and shellfish from publicly owned and managed offshore waters. The money could be used for government fishery management, as Australia does. A third method involves setting up programs to certify sustainable fisheries, as the Marine Stewardship Council has done for six fisheries.

There is also a need to reduce by catch levels. Ways to do this include using wider-mesh nets to allow smaller species and smaller individuals of the targeted species to escape, having observers on fishing vessels, and licensing boats to catch several species instead of only one target species. In addition, laws can be enacted that prohibit throwing edible and marketable fish back to sea. Namibia and Norway have done this, with the law enforced by onboard observers.

Another strategy to achieve sustainable fisheries is to establish protected areas. Ways to do this include closing fisheries during certain seasons and establishing no-fishing or protected marine areas to allow depleted fish species to recover. Also, integrated coastal management programs can be used to promote both sustainable fishing and the ecological health of marine ecosystems. Another strategy is to use labels that allow consumers to identify fish that have been harvested sustainably.

Government agricultural policy

How to Government Agricultural Policies Affect Food Production? Agriculture is a financially risky business. Whether farmers have, a good year or a bad year depends on factors over which they have little control: weather, crop prices, crop pests and diseases, interest rates, and the global market. Because of the need for reliable food supplies despite fluctuations in these factors, most governments provide various forms of assistance to farmers and consumers. Governments use three main approaches to do this. One is to keep food prices artificially low. This makes consumers happy but means farmers may not be able to make a living.

Another is to give farmers subsidies to keep them in business and encourage them to increase food production. Globally, government price supports and other subsidies for agriculture total more than $500 billion per year (including $100 billion per year in the United States). If government subsidies are too generous and the weather is good, farmers may produce more food than can be sold. The resulting surplus depresses food prices, which reduces the financial incentive for farmers in developing countries to increase domestic food production.

A third approach is to eliminate most or all price controls and subsidies and let farmers and respond to market demand without government interference. However, some analysts urge that any pnaseout of farm and fishery subsidies should be coupled with increased aid for the poor and the lower middle class, who would suffer the most from any increase in food prices. Many environmentalists say that instead of eliminating all subsidies we should use them to reward farmers and ranchers who protect the son, conserve water, reforest degraded land, protect and restore wetlands, conserve wildlife, and practice more sustainable agriculture and fishing.

Protecting food resources: using conventional chemical pesticides to control pests

What is a Pest? A pest is any species that competes with us for food, invades lawns and gardens, destroys wood in houses, spreads disease, or is simply a nuisance worldwide, only about 100 species of plants which we call weeds), animals (mostly insects), fungi and microbes (which can infect crop plants and live stock animals) cause about 90% of the damage to the crops we grow.

Most pest species are r-selected or opportunist species (Figure 8-10). Typically, such species reproduce rapidly, spread quickly when a disturbance opens up a new habitat or niche (as in the early stages of ecological succession, Figure 7-12), and can temporarily take over a biological community. Insects cause much of the damage to the crops we grow. This is not surprising because insects make up about 75% of the earth's known species, reproduce rapidly, and through natural selection can rapidly develop protective traits such as generic resistance to pesticides. As we try to keep a small number of insect pests from eating some of the food we grow, we should also remember that our lives depend on the many important ecological roles that insects play.

In natural ecosystems and many polyculture agro ecosystems, natural enemies (predators, parasites, and disease organisms) control the populations of 50-90% of pest species as part of the earth's ecosystem services and help keep any one species from taking over for very long. When we change agriculture from polyculture to monoculture and spray fields with huge amounts of pesticides, we-upset many of these natural population checks and balances. Then we must devise ways to protect our\monoculture crops, tree plantations, and lawns from insects and other pests that nature once controlled at no charge.

What are Pesticides? To help control pest organisms, we have developed a variety of pesticides (or biocides): chemicals to kill organisms we consider undesirable. Common types of pesticides include insecticides (insect killers), herbicides (weed killers), fungicides (fungus killers), nematocides (roundworm killers), and rondenticides (rat and mouse killers).

Plants have been producing chemicals to ward off or poison herbivores that feed on them for, about 225 million years. This is a never-ending, ever changing process: herbivores overcome various /plant -defenses through natural selection; then the plants use natural selection to develop new defenses. As the human population grew and agriculture spread, people began looking for ways to protect their crops, mostly by using chemicals to kill or repel insect pests. Sulfur was used as an insecticide well before 500 B.C. by the 1400s; people were applying toxic compounds of arsenic, lead, and mercury to crops as insecticides. Farmers abandoned this approach in the late 1920s when the increasing number of human poisonings and fatalities prompted a search for less toxic substitutes.

In the 1600s, farmers used nicotinic sulfate, extracted from tobacco leaves, as an insecticide. In the mid-1800s, two more natural pesticides were introduced: pyrethrum (obtained from the heads of chrysanthemum flowers) and rotenone (extracted from the roots of various tropical forest legumes). These first-generation pesticides were mainly natural chemicals borrowed from plants that had been defending themselves from insects for eons. A major pest control revolution began in 1939, when entomologist Paul Miiller discovered that DDT (dichloro diphenyl trichloro ethane), a chemical known since 1874, was a potent insecticide. DDT, the first of the 'so-called/second-generatkm pesticides, soon became the world's most used pesticide, and Miiller received the Nobel Prize in 1948 for his discovery. Since then, chemists have made hundreds of other second-generation synthetic chemical pesticides.

How Pesticides Are Used Today? Since 1950, pesticide use has risen more than 50-fold, and most of today's pesticides are more than ten times as toxic as those used in the 1950s. Worldwide, about 2.3 million metric tons (2.5 million tons) of second-generation pesticides—worth about $44 billion—are used yearly. About 75% of these chemicals are used in developed countries, but use in developing countries is soaring.

Since 1980, pesticide use for growing crops has leveled off in the United States. About 25% of pesticide use in the United States is for ridding houses, gardens, lawns, parks, playing fields, swimming pools, and golf courses of pests. According to the U.S. Environmental Protection Agency (EPA), the average lawn in the United States is doused with ten times more synthetic pesticides per hectare than U.S. cropland. The EPA estimates that 84% of U.S. homes use pesticide products such as bait boxes, pest strips, bug bombs, flea collars, and pesticide pet shampoos and weed killers for lawns and gardens. Each year, more than 250,000 people in the United States become ill because of household pesticide use. Such pesticides are a major source of accidental poisonings and deaths for children under age 5.

Some pesticides, .called broad-spectrum agents, are toxic to many species others, called selective or narrow spectrum agents, are effective against a narrowly defined group of organisms. Pesticides vary in their persistence, the length of time they remain deadly in the environment. In 1962, biologist Rachel Carson warned against relying on synthetic organic chemicals to kill insects and other species we deem pests (Individuals Matter, above).

What Is the Case for Pesticides? Proponents of conventional chemical pesticides contend that the benefits outweigh their harmful effects. Conventional pesticides have a number of important benefits.

First, they save human lives. Since 1945, DDT and other chlorinated hydrocarbon and organophosphate insecticides probably have premature deaths of at least 7 million people from insect transmitted diseases such as malaria.(carried by the Anophilus mosquito), bubonic plague (fleas); typhus,(body lice arid fleas).

Second, pesticides increase profits for farmers. Pesticide Company's estimate that every $1 spent on pesticides leads to an increase in U.S. crop yields worth approximately $4 (But studies have shown, this benefit drops to about $ 2 if the harmful effects of pesticides are included.

Third, chemical pesticides work faster and better than alternatives. Pesticides control most pests quickly a reasonable cost, have a long shelf life, are easily shipped and applied, and are safe when handled properly. When genetic resistance occurs, farmers can use stronger doses or switch to other pesticides.

Fourth, when pesticides are used properly, their health risks are /considered insignificant compared with their benefits,. According to Elizabeth Whelan, director of the American Council on Science and Health (ACSH), which presents the position of the pesticide industry? The reality is that pesticides, when used in the approved regulatory manner/pose no risk to either farm workers or consumers." According to the EPA the worst-case scenario is that synthetic pesticides in food cause 0.5-1% of all cancer-related deaths in the United States or 3,000-6,000 premature deaths per year—far less than the estimated number of lives saved each year by pesticides.

Fifth, newer pesticides are safer and more effective than many older pesticides. Greater use is being made of botanicals, and micro botanicals, derived originally from plants, which are safer to users arid less damaging to the environment Genetic engineering (Figure 5.10) is also being used to develop pest-resistant crop strains and genetically altered crops that produce pesticides.

Finally, many new pesticides are used at very low rates per unit area compared with older products. For example, application amounts per hectare for many new herbicides are 1/100 the rates for older ones, and genetically engineered crops could reduce the use of toxic insecticides. Scientists continue to search for the ideal pest killing chemical, which would have these qualities. The search continues, but so far no known natural or synthetic pesticide chemical meets all or even most of these criteria.

What Is the Case against Pesticides? Opponents of widespread pesticide use believe their harmful effects outweigh their benefits. They cite several major problems with the use of conventional pesticides. A major problem is that their widespread use accelerates the development of genetic resistance to pesticides. Insects breed rapidly, and within 5-10; years (much sooner in tropical areas) they can develop immunity to pesticides through directional natural selection and come back stronger than before. Weeds and plant disease organisms also develop genetic resistance, but more slowly. Since 1945, about 1,000 species of insects, mites,; weed species, plant diseases, and rodents (mostly rats) have developed genetic resistance to, one or more pesticides (Figure 5.18).

Because of genetic resistance, many insecticides (such as DDT) no longer protect people from insect-transmitted diseases in some parts of the world. This has led to the resurgence of such diseases as malaria. Genetic resistance can also put farmers on a pesticide treadmill, whereby they pay more and more for a pest control program; that often becomes less and less effective.

Another problem is that broad-spectrum insecticides kill natural predators and parasites that 'help control the populations of pest species. Wiping out natural predators can unleash new pests whose population their predators had previously held in check and cause other unexpected effects (Connections). Of the 300 most destructive insect pests in the United States currently, 100 were secondary pests that became major pests after widespread use of insecticides.

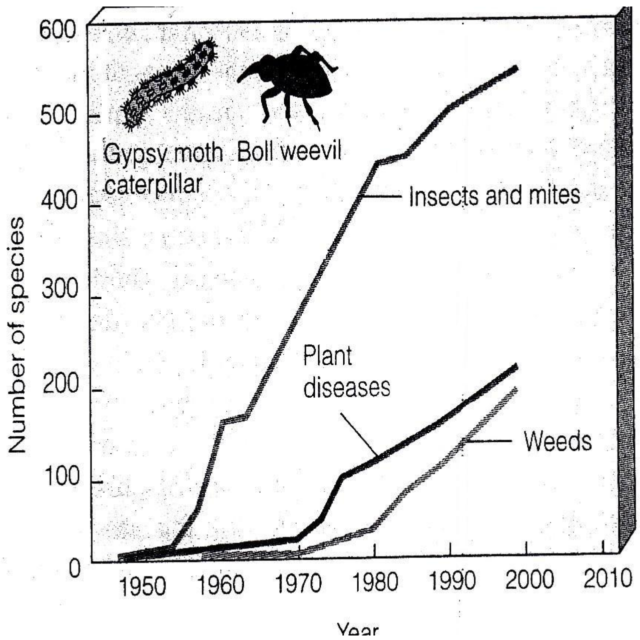


Figure 5.18: Rise of genetic resistance to pesticides, 1945-98

Also, pesticides1: do not stay put. According to the U.S. Department of Agriculture (USDA), no more than 2% (and often less than 0.1%) of the insecticide applied to crops by aerial or ground spraying reaches the target pests. Also, less than 5% of herbicide applied to crops reaches the target weeds. Pesticides that miss their target pests can end up in the air, surface water, groundwater, bottom sediments, food, and non target organisms, including humans and wildlife:. Crops that have been genetically altered to release small amounts of pesticides directly to pests can help overcome this problem. But this can promote genetic resistance to such pesticides.

Some pesticides harm wildlife. According to the USDA and the U.S. Fish and Wildlife Service, each year pesticides applied to cropland in the United States wipe out about 20% of U.S. honeybee colonies and damage another 15%. This costs farmers at least $200 million per year from reduced pollination of vital crops. Pesticides also kill more than 67 million birds and 6-14 million fish, and menace about 20% of the endangered and threatened species in the United States.

Finally, some pesticides can threaten human health. The WHO and the UN Environment Programme (UNEP) estimate that pesticides seriously poison 3 million agricultural workers in developing countries (at least 300,000 in the United, States) each year. This causes an estimated 18,000 deaths (about 25 in the United States)—an average of 490 premature deaths each day.

Health officials believe the actual number of pesticide-related illnesses and deaths among the world's farm workers probably is greatly underestimated because of poor records, lack of doctors and disease reporting in rural areas, and inaccurate diagnoses.

Each year 110,000 Americans, mostly children, get sick from misuse or unsafe storage of pesticides in the home, and about 20 die. According to studies by the National Academy of Sciences, exposure to pesticide residues in food causes 4,000-20,000 cases of cancer per year in the United States. Because roughly 50% of people with cancer die prematurely, this amounts to about 2,000-10,000 premature deaths per year in the United States from exposure to legally allowed pesticide residues in foods. This is higher than the EPA estimate of 3,000-6,000 premature deaths per year. Some scientists are becoming increasingly concerned about possible genetic mutations, birth defects, nervous system disorders (especially behavioral disorders), and effects on the immune and endocrine systems from long term exposure to low levels of various pesticides.

How Well Is the Public Protected from Exposure Pesticides in the United States? Here are two pieces of good news. First, the EPA banned or severely restricted the use of 56 active pesticide ingredients between 1972 and 2002. The banned chemicals include most chlorinated hydrocarbon insecticides, several carbamates and organophosphates, and the systemic herbicide 2,4,5-T (Silvex).

Second, the 1996 Food Quality Protection Act (FQPA) increased public protection from pesticides. It requires manufacturers to demonstrate the safety of active ingredients in new pesticide products for infants and children. The EPA must also consider exposure to more than one pesticide when setting pesticide tolerance levels.

Environmentalists believe U.S. pesticide laws should be strengthened further to help prevent contamination of groundwater by pesticides, improve the safety of farm workers who are exposed to high levels of pesticides, and allow citizens to sue the EPA for not enforcing the law. Pesticide manufacturers strongly oppose such changes.

Here is some bad news. Banned or unregistered pesticides may be manufactured in the United States and exported to other countries (Connections, above). According to scientific literature renewed by the EPA approximately 165 of the active ingredients approved for use in U.S. pesticide products are known or suspected human carcinogens. By 2002, use of only 41 of these chemicals had been banned by the EPA or discontinued voluntarily by manufacturers.

Here is more bad news. According to studies by the National Academy of Sciences, federal laws regulating pesticide use in the United States are inadequate and poorly enforced by the EPA, Food and Drug Administration (FDA), and USDA. Another study by the National

Academy of Sciences found that up to 98% of the potential risk of developing cancer from pesticide residues on food grown in the United States would be eliminated if EPA standards were as strict for pre-1972 pesticides as they are for later ones.

Representatives from pesticide companies dispute these findings. Indeed, the food industry denies that eating food that has been grown using pesticides for the past 50 years have ever harmed anyone in the United States. The industry also claims [that the benefits of pesticides far outweigh their disadvantages. Pesticide control laws in the United States could be improved. But most other countries (especially developing countries) have not made nearly as much progress as the United States in regulating pesticides.

Protecting food resources: alternatives to conventional chemical pesticides

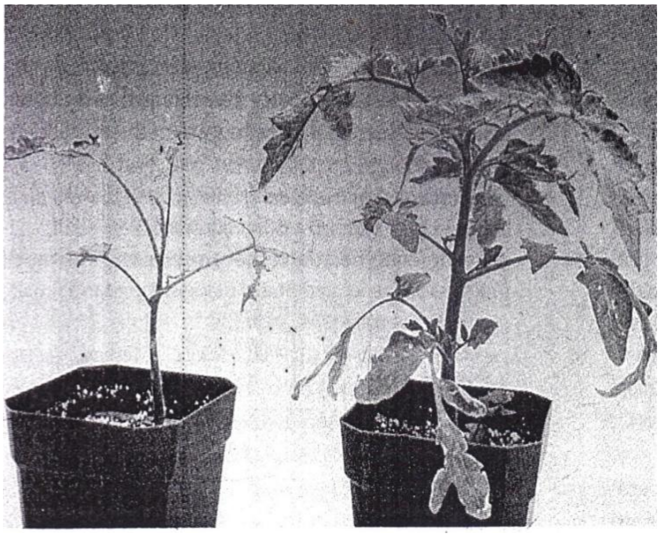


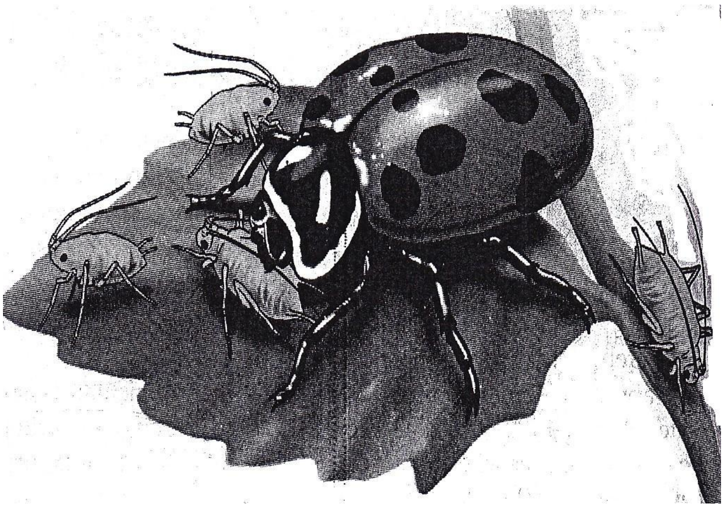
Figure 5.19: Solutions; results of one example of using genetic engineering to reduce pest damage. Both tomato plants were exposed to destructive caterpillars. The normal plants leaves are almost gone (left), whereas the genetically altered plant (right) shows little damage.

What Are Other Ways to Control Pests? Many scientists believe we should greatly increase the use of biological, ecological, and other alternative methods for controlling pests and diseases that affect crops and human health. A number of methods are available.

One is the use of certain cultivation practices. Examples are rotating the types of crops planted in a field each year, adjusting planting times so major insect pests either starve or get eaten by their natural predators, and growing crops' in areas where their major pests do not exist. Other strategies involve planting trap crops to lure pests away from the main crop and planting rows of hedges or frees around fields to hinder insect invasions and provide habitats for their natural enemies (with the added benefit of reduced soil erosion. Also, farmers can increase the use of polyculture, which uses plant diversity to reduce losses to pests.

Genetic engineering (Figure 5.10) can be used to speed up the development of pest- and disease-resistant crop strains (Figure 5.19). However, there is controversy over whether the projected advantages of the increasing use of genetically modified plants and foods outweigh their projected disadvantages (Figure 16.11).

We can increase the use of biological pest control It involves importing natural predators (Figure 16-20), parasites, and disease-causing bacteria and viruses to help regulate pest populations. This approach focuses on selected target species, is nontoxic to other species, and minimizes genetic resistance. Also, it can save large amounts of money—about $25 for every $1 invested in controlling 70 pests in the United States. However, biological control has some disadvantages. Biological agents cannot always' be mass produced. They are often slower acting and more difficult to apply than conventional pesticides and the agents can sometimes multiply and become pests themselves. In addition, the biological agents must be protected from pesticides sprayed in nearby fields.



Fgure 5.20: Solutions; biological pest control. An adult convergent ladybug (right) is consuming an aphid (left)

Another strategy is to use insect birth control. This involves raising males of insect pest species in the SI oratory and sterilizing them by exposure to radiation or chemicals. Then the sterile males are released into an infested area to mate unsuccessfully with fertile wild females. This method has been used to control the screwworm fly, a major livestock pest from the southeastern United States, and the Mediterranean fruit fly (medfly) during a 1990 outbreak in California.

Problems include high costs, difficulties in knowing the mating time .and behavior of each target insect, and the large number of sterile males needed. In addition, there are few species for which strategy works, and sterile males must be released continually to-prevent pest resurgence.

Sex 0ttractants can also be used. These chemicals, called pheromones, can lure pests into traps or attract their natural predators into crop fields (usually the more effective approach). More than 50 companies worldwide sell about 250 pheromones to control pests. Some advantages are that these chemicals attract only one species, work in trace amounts, have little chance of causing genetic resistance, and are not harmful to nontarget species. However, it is costly and time consuming to identify, isolate and produce the specific sex attractant for each pest or predator.

We can also use hormones that disrupt an insect's normal life cycle (Figure 5.21), causing the insect to fail to reach maturity and reproduce. Insect hormones have the same advantages as sex attractants. However, they I take weeks to kill an insect, often are ineffective with large infestations of insects, and (sometimes break /down before they can act. They must be applied at exactly the right time in the target insect's life cycle and can sometimes affect the target's predators and other nonpest species. They are also difficult and costly to produce.

Some farmers have been able to control some insect pests by spraying them with hot water. This has worked well on cotton, alfalfa, and potato fields and in citrus groves in Florida. The cost is roughly equal to that of using chemical pesticides. Another strategy is to expose foods to high-energy gamma radiation. Such food irradiation extends food shelf life and kills insects and parasitic worms (such as trichinae in pork). It also kills harmful bacteria. Examples are salmonella (which infects at least 51,000 Americans and kills 2,000 each year) and E. coli (which infects more than 20,000 Americans and kills about 250 each year). According to the U.S. FDA and the WHO, more than 2,000 studies show that foods exposed to low doses of gamma radiation are safe for human consumption.

Critics of irradiating food argue that it forms trace amounts of certain chemicals which have caused cancer in laboratory animals. They also point out that the long-term health effects of eating irradiated food are unknown and consumers do not want old and possibly less nutritious food made to; appear fresh and healthy by irradiation. They believe that all irradiated food should be labeled so consumers can make informed choices. Another problem is that poorly protected facilities for food irradiation contain radioactive isotopes that terrorists could steal: and use to make dirty nuclear weapons.

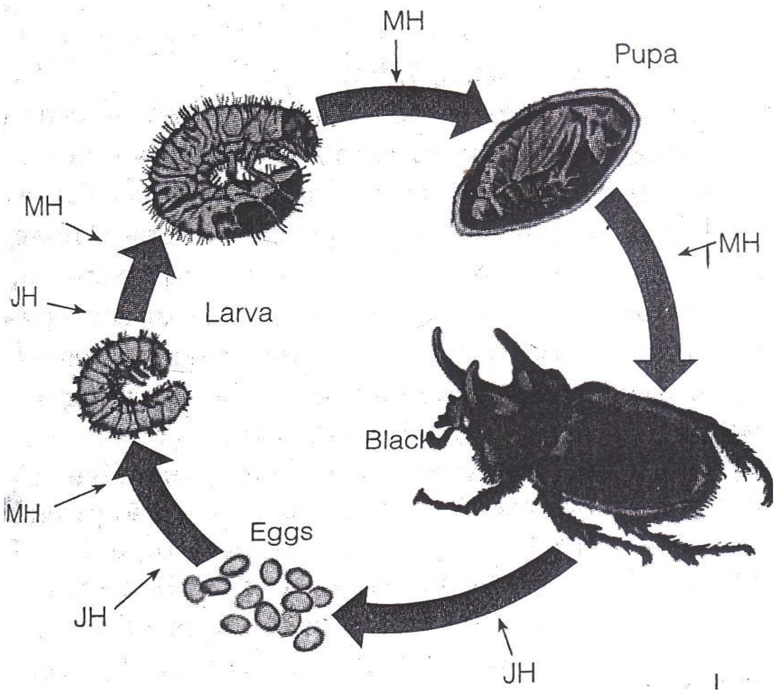


Figure 5.21: For normal insect growth, development, and reproduction to occur, certain juvenile hormones (JH) and melting hormones (MH) must be present at genetically determined stages in the insect's life cycle. If applied at the proper time, synthetic hormones disrupt the life cycles of insect pests and help control their populations.

Is Integrated Pest Management the Answer?

An increasing number of pest control experts and farmers believe the best way to control crop pests is a carefully designed integrated pest management (IPM) program. In this approach, each crop and its pests are evaluated as parts of an ecological system. Then a control program is developed that includes cultivation and biological and chemical methods applied in proper sequence and with the proper timing.

The overall aim of 1PM is not to eradicate pest populations but to reduce crop damage to an economically tolerable level. Fields are monitored carefully to determine when an economically damaging level of pests has been reached. When this happens farmers first use biological methods (natural predators, parasites/and disease organisms) and cultivation controls, including vacuuming up harmful bugs. Small amounts of insecticides (mostly based on natural insecticides produced by plants) are applied only as a last resort. Also; different chemicals are used to slow development of genetic resistance and to avoid killing predators of pest species.

In 1986, the Indonesian government banned the use of 57 of the 66 pesticides used on rice and phased out pesticide subsidies over a 2-year period. It also launched a nationwide education program to help farmers switch to IPM. The results were dramatic: Between 1987 and

1992, pesticide use dropped by 65%, rice production rose by 15%, and more than 250,000 farmers were trained in IPM techniques. Norway and Sweden have imposed substantial taxes on conventional pesticides, with the goal of cutting current pesticide use by 25-50%.

The experiences of various countries show that a well-designed IPM program can reduce pesticide use and pest control costs by 50-90%, decrease pre harvest pest-induced crop losses by 50%, and improve crop yields. It can also reduce inputs of fertilizer and irrigation water and slow the development of genetic resistance because pests are assaulted less often and with lower doses of pesticides. Thus IPM is an important form of pollution prevention that reduces risks to wildlife and human health Consumers Union estimates that if all U.S farmers practiced IPM by 2020, public health risks from pesticides would drop by 75%.

Despite its promise, IPM, like any other form of pest control, has some disadvantages. It requires expert knowledge about each pest situation and is slower acting than conventional pesticides. In addition, methods developed for a crop in one area might not apply to areas with even slightly different growing conditions. Also, initial costs may be higher, although long-term costs typically are lower than those of using conventional pesticides. Widespread use of IPM is hindered by government subsidies of conventional chemical pesticides and opposition from agricultural chemical companies, whose pesticide sales would drop sharply. In addition, farmers get most of their information about pest control from pesticide salespeople (and in the United States from USDA county farm agents). Most of these advisers do not have adequate training in IPM.

A1996 study by the National Academy of Sciences recommended that the United States shift from chemically based approaches to ecologically based pest man agreement approaches. A growing number of scientists urge the USDA to promote IPM in the United States. Ways to do this include adding a 2% sales tax on pesticides and using their avenue to fund IPM research and education. We could also set up a federally supported IPM demonstration project on at least one farm in every county, and train USDA field personnel and county farm agents in IPM so they can help farmers use this alternative. Farmers who use IPM or other approved alternatives to pesticides could receive federal and state subsidies, and perhaps government-backed crop insurance. As effective IPM methods are developed for major pest species, the government could gradually phase out subsidies to farmers who depend almost entirely on conventional chemical pesticides.

Solutions: more sustainable agriculture

What Is More Sustainable Agriculture? As we have seen in this chapter, two major ways to increase the world's food production are to increase crop yields per hectare and to increase the amount of land used to grow crops. The total area of cropland is unlikely to expand because of a lack of affordable and environmentally sustainable land. In addition, increasing the yields per area of existing cropland may be limited in some areas because of a lack of water for irrigation, reduced genetic diversity needed to develop new crop strains, slowing of increases in yields per hectare, and the environmental effects of food production, which degrade existing cropland.

If these projections are correct, there are three main ways to reduce hunger and malnutrition and the harmful environmental effects of agriculture. One is to slow population growth. Another is to reduce poverty so people can grow or buy enough food for their survival and good health. The third is to develop and phase in systems of more sustainable agriculture or low-input agriculture (also called organic farming) over the next three decades. Currently, organic farming is used on less than 1% of the world's cropland (0.2% in the United States) but on 6-10% of the cropland in many European countries. However, this type of farming is growing rapidly. In 2002, it was a $25 billion global market and a $12 billion market in the United States.

The U.S. Department of Agriculture has established several rules for organic food production. First, crops ate grown on land that has not been fertilized with selvage sludge or chemical fertilizers. Soil health is managed primarily through use of organic fertilizers, crop rotation, and planting coyer crops.

Second, organic farmers do not use chemical insecticides. They treat pests and plant diseases primarily with natural insect predators, traps, and insect repellents. They also do not use chemical herbicides. Instead, weeds are, controlled mostly by mulching and weeding or mechanical cultivation.

Third, genetically engineered crops and livestock animals are not used. Fourth, animals used to provide meat and eggs must be raised on pure organic feed and receive no growth hormones or antibiotics, must also be raised under living conditions that allow for exercise, freedom of movement, and reduction stress. Finally organic food cannot be irradiated.

Figure 5.21 lists the major components of ore sustainable, low-input agriculture. In 2002, agricultural scientists Paul Mader and David Dubois reported the results of a 21-year study comparing organic and conventional farming. Their results and those from other studies have shown that for most crops low input organic farming has a number of advantages over conventional high-input, farming. They include use of up to 56% less energy per unit of yield, and improved soil health and fertility. Organic farming also provides more habitats for wild plant and animal species arid generally is more profitable for the farmer than high-input f arming.

Most proponents of more sustainable agriculture are not opposed to high-yield agriculture. Instead, they see it as vital for protecting the earth's biodiversity by reducing the need to cultivate new and often marginal land. They call for using environmentally sustainable forms of both high-yield polyculture and high-yield monoculture for growing crops.

How Can We Make the Transition to More Sustainable Agriculture?

A growing number of agricultural analysts say that over the next 30 years we need to make a transition from unsustainable and environmentally harmful agriculture to pre sustainable forms of agriculture. Analysts suggest four major strategies to help farmers make the transition to more sustainable agriculture and improving human nutrition. Second, set up demonstration projects throughout each country so farmers can see how sustainable agricultural systems work. Third, increase agricultural aid to developing countries, with emphasis on developing more sustainable, low-input agriculture. Fourth, establish training programs in sustainable agriculture for farmers and government agricultural officials and encourage the creation of college curricula in sustainable agriculture and human nutrition.

Phasing in more sustainable agriculture involves applying the four principles of sustainability to producing food. The goal is to feed the world's people while sustaining and restoring the earth's natural capital. See the website material for this chapter for some actions you can take to help promote more sustainable agriculture.

6 Biosafety

The loss or degradation of biodiversity can have important economic, environmental, and social consequences. Altering a watershed, for example, not only leads to the potential loss of an ecosystem through loss of habitat but may also create economic costs for water filtration in cities using its water. And it is not enough simply to preserve those biological resources that are known to be useful to humans now we may also be losing potentially beneficial compounds and materials that are, as yet, undiscovered.

Biodiversity loss also has social consequences, in its impact on people's livelihoods and lifestyles this is the unmeasured cost of losing cultural traditions. The loss of key elements of an ecosystem can alter the balance between its components and lead to long-term or permanent changes. Biodiversity loss can also affect human health, as our health is largely dependent on the quality of the ecosystem in which we live loss of plant or animal species can affect the quality of water or soil, for instance.

The main pressures on biodiversity result from land use changes; unsustainable use and exploitation of natural resources; global climate change; and industrial pollution. At the same time, biotechnology is introducing new organisms and their effect on existing organisms and habitats also needs to be considered. In some instances, these pressures can actually be positive for biodiversity. Agricultural activity sometimes improves the habitat and even helps increase the variety of species; the Mediterranean basin is considered a biodiversity "hot spot" in part because of its public administration, monitoring and enforcement, as well as the private costs of implementation.

Since market-based instruments that change the prices of biodiversity-impacting products are often cost-effective and generally under utilised they should be promoted. However, it will still often be necessary to use non-market-based instruments in the policy mix. There is also a need to work at the international level to implement biodiversity management policies, for example in development co operation or in policies to protect migratory species and aquatic resources. Moreover, biodiversity-related resources have non-use values to people everywhere that need to be reflected in local use decisions without compromising local economic development.

Biodiversity Management

Incentive measures are the basis of a market approach to biodiversity management. Such measures help reconcile differences between the value of biodiversity-related resources to individuals and the value of biodiversity to society as a whole. They increase the-cost of activities that damage ecosystems important for biodiversity and reward biodiversity conservation and enhancement/restoration. Farmers who receive a government payment for maintaining biological diversity on their land, for example, will be more willing to use farm practices that sustain biodiversity values. The idea of using incentives to achieve particular biodiversity objectives often requires a method for gauging the value of biodiversity. Unfortunately, reaching consensus on such method(s) is not always easy.

Economic valuation can sometimes offer a solution if monetary measures of the impacts involved can be obtained or implied such as the cost of travel, and related expenses, for visiting natural areas. However, it is more difficult to quantify the more aesthetic or cultural values involved, for example, in non-use of biodiversity, such as declaring a mountainside an ecological conservation area. For those non-use values, techniques to get people to "reveal" biodiversity's value to them are needed. Although some debate continues about how far economic valuation techniques can be used to value non-marketed environmental resources such as landscapes, the acceptability and use of these techniques continue to grow. This is due mainly to theoretical advances in the methodologies underlying these techniques.

Market Creation

Markets are created by removing barriers to trade, including the establishment and assignment of well-defined and stable property and/or user rights. Market creation is based on the premise that holders of these rights will maximise the value of their resources over time, thereby optimising biodiversity use, conservation, and restoration. Market creation therefore involves a broader approach than the simple use of market incentives.

Governments have two important roles to play in supporting markets for biodiversity-related resources. First, they need to establish the right framework conditions for private and public operators to supply biodiversity-related resources efficiently to users. They also need to apply the right policy instruments to ensure that public biodiversity-related goods amt devices are provided in the most efficient and effective manner. Three issues need special attention. First, the absence of appropriate information can inhibit the development and implementation of market approaches to biodiversity conservation, use, and restoration.

Information can be provided through such mechanisms as labeling, certification and technical capacity-building. Scientific knowledge is also important, so governments need to develop policies that establish the right conditions for new knowledge to emerge related to biodiversity conservation. Indicators to monitor biodiversity change will also be important, along with the active and early engagement of stakeholders in developing and implementing biodiversity management policies.

Local community networks that identify and support local biodiversity objectives can make important contributions in this regard. Also, markets need to be periodically monitored to ensure they actually result in net benefits for society as a whole. A number of specific markets have already developed around biodiversity-related activities. Examples include; organic agriculture; sustainable forestry; non-timber forest products; genetic resources; and ecotourism. Two highly successful examples where the instruments themselves created the market are trading in access to fishing rights and transferable development rights to land.

The emergence of private parks in many regions of the world also demonstrates that there is scope for capturing public values in. private markets. For those parks, the private value of their uniqueness is high enough to support public biodiversity objectives. However, since the public value of the parks will typically be greater than the private values, economic incentives that capture some of these additional public values would improve the efficiency and effectiveness of biodiversity management.

Importance of Biosafety

Products of modern biotechnology might also affect biodiversity, and thus raise environmental safety issues. Genetically engineered crops are no longer an idea of the future, but have well and truly arrived. Crops such as maize, soybean, rapeseed and cotton are being approved tor commercial use in an increasing number of countries. The OECD has been active on such issues since the mid-1980s. From 1996 to 2004, there was more than a 47-fold increase in the area grown with transgenic crops worldwide, reaching 81.0 million hectares.

In 2004, there were 14 countries that grew 50,000 hectares or more: the US grew 59% of the world total, followed by Argentina (20%), Canada (6%), Brazil (6%), China (5%), Paraguay (2%), India (1%), and South Africa (1%). In addition, Uruguay, Australia, Romania, Mexico, Spain and the Philippines each had smaller scale cultivation of less than 1% of the total. Most of this cultivation was devoted to soybean (60%), maize (23%), cotton (11%), and rapeseed (6%). So far, most commercialization has focused on these crops, and the genetic engineering has involved two traits insect resistance and herbicide tolerance.

The trend for an increase in the transgenic crop area seems set to continue, given the large range of genetically engineered crops in research and development In all OECD countries, a notification or registration has to be made to obtain approval for the commercial use of a genetically engineered crop whether for planting and growing or for use in human or animal foods. Such approval is always based on a safety assessment by national authorities, which in turn is based on scientific information regarding the crop, its specific trait, and the receiving environment. It is important for governments to ensure that good quality safety information is publicly available and, where possible, to adopt international approaches to risk and safety assessment that ensure the efficiency of the risk assessment process.

Biosafety Assessments

One of the primary goals of the OECD's work on biosafety in the past decade has been to promote harmonisation among member countries of notifications and registrations of biotechnology products. Such harmonisation aims to ensure that the information used in risk/safety assessments, as well as the methods used to collect such information, is as similar as possible. This can lead to countries recognising or even accepting information from- one another's safety assessments, and it generates significant benefits.

It increases mutual understanding among member countries of each other's risk assessments; it avoids duplication of effort; it saves on scarce resources; and it increases the efficiency of the risk/ safety assessment process. This in turn improves safety, while reducing unnecessary barriers to trade. For harmonisation to be possible among member countries, it is important that they have similar approaches to risk/safety assessment. Earlier OECD work on risk assessment demonstrated that such assessment should be based on the characteristics of the organism, the introduced trait, the environment into which the organism is introduced, the interaction between these, and the intended application. This work has formed the basis for environmental risk/ safety assessment that is now globally accepted. The similarity of approach was reinforced -by the fact that most genetically engineered organisms are developed from organisms such as crop plants whose biology is well understood.

This allows the risk assessor to draw on previous knowledge and experience with the introduction of plants and microorganisms into the environment. The process takes account of a wide range of attributes including, for example, knowledge and experience with the plant, including its flowering/reproductive characteristics, ecological requirements, and past breeding experiences. It is not just that national authorities use the same concepts and principles in risk assessment.

OECD countries also share a remarkably high degree of similarity in the questions and issues addressed in risk/safety assessments as outlined in national laws, regulations, and guidance documents. Of course, national authorities also request some regulatory information which is specific to the local environment. But nevertheless, much of the information used in risk/safety assessment that relates to the biology of crop plants and microorganisms is similar or virtually the same in all assessments involving the same organism.

So a major focus of the OECD's work on harmonisation is to compile the biological information common to the risk/safety assessment of a number of transgenic products, focusing on two specific categories: the biology of the host species or crop; and traits used in genetic modifications. The aim is to encourage information-sharing and prevent duplication of effort among countries by avoiding the need to address the same common issues in each application involving the same organism or trait. The resulting Consensus Documents on biology and traits are not intended to be a substitute for a risk/safety assessment, because they address only the generic part of the information that member countries believe is relevant to risk/safety assessment. They are intended to be a "snapshot" of current information, for use during the regulatory assessment of products of biotechnology. Nevertheless, they make an important contribution to environmental risk/safety assessment and help prevent duplication of effort among countries.

An additional challenge is to transfer the knowledge obtained by countries with experience in risk/safety assessment to all those who need it, including non-OECD countries. This enables those involved in risk assessment of transgenic products to easily obtain information developed from previous experiences. The OECD has established information exchange mechanisms and databases to support this process. One such mechanism, BioTrack Online, has been one of the best sources of information on regulatory developments in OECD countries, as weir as field trials and approvals of commercial products. The OECD's Product Database contains information on the safety of genetically engineered crops in commercial use, as well as links to the Web sites of national authorities. BioTrack Online is publicly available on the Internet, and in recent years has been linked with the Biosafety Clearing House (BCH) which is part of the Cartagena Biosafety Protocol to the UN Convention on Biological Diversity. The Cartagena Protocol is intended to lay the foundation for a global system for assessing and managing the impact of living modified organisms on biodiversity.

Identify Genetically Engineered Crops

Confusion can arise when national authorities share information on the same-genetically engineered crop if different names or descriptions are used for the same type of maize or cotton. To avoid this problem, the OECD has developed a system of "unique identifiers" for transgenic plants. A unique nine-digit letter""and" number code is given to each new transgenic plant that is approved for commercial use and becomes its "name" worldwide. So, for instance, maize developed by Monsanto to be resistant to insect pests has a unique identifier of MON- Ø Ø 810-6, while DD- Ø 1951A-7 denotes cotton developed by DuPont.

The guidance provides for the developers of a new transgenic product to generate the identifier. Once approved, national authorities can forward the unique identifier for inclusion in the OECD's database. OECD countries are already using the system. The EU recently adopted it as its system for generating unique identifiers and it has been recognised as a mechanism for unique identification to be used within the context of the Cartagena Protocol. The OECD has been forwarding unique identifiers to the Biosafety Clearing House which is a key element of the Protocol's activities. The system works well for genetically engineered crops and the OECD is now considering how the identifier tool can be extended beyond crops to micro-organisms and animals. Thanks to unique identifiers, all stakeholders, including the public, will be able to access solid and reliable information when making their judgments about safety.

Cartagena Protocol on Biosafety

On 29 January 2000, the Conference of the Parties to the Convention on Biological Diversity adopted a supplementary agreement to the Convention known as the Cartagena Protocol on Biosafety. The Protocol seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology. It establishes an advance informed agreement (AIA) procedure for ensuring that countries are provided with the information necessary to make informed decisions before agreeing to the import of such organisms into their territory.. The Protocol contains reference to a precautionary approach and reaffirms the precaution language in Principle 15 of the Rio Declaration on Environment and Development. The Protocol also establishes a Biosafety Clearing-House to facilitate the exchange of information on living modified organisms and to assist countries in the implementation of t.ie Protocol.

History

Pursuant to Article 19, paragraph 3, of the Convention on Biological Diversity, the Conference of the Parties, by its decision 11/5, established an Open-ended Ad Hoc Working Group on Biosafety to develop a draft protocol on biosafety, specifically focusing on transboundary movement of any living modified organism resulting from modern biotechnology that may have adverse effect on the conservation and sustainable use of biological diversity. The Open-ended Ad Hoc Working Group on Biosafety held six meetings between July 1996 and February 1999. At its conclusion, the Working Group submitted a draft text of the Protocol, as well as the outstanding concerns of the Parties, for consideration by Conference of the Parties at its first extraordinary meeting, convened for the purpose of adopting a protocol on biosafety to the Convention on Biological Diversity.

In accordance with decision IV/3, the first extraordinary meeting of the Conference of the Parties was opened on 22 February 1999, in Cartagena, Colombia. The Conference of the Parties was not able to finalise its work in the time available. As a result, by decision EM-I/1, the Conference of the Parties suspended its first extraordinary meeting and agreed that it should be reconvened as soon as possible and in any event no later than the fifth meeting of the Conference of the Parties.

The resumed session took place in Montreal from 24 to 29 January 2000 and was preceded by regional and interregional informal consultations from 20 to 23 January 2000 at the same venue. On 29 January 2000, the Conference of the Parties, by its decision EM-I/3, adopted the Cartagena Protocol on Biosafety to the Convention on Biological Diversity and approved interim .arrangements pending its entry into force. It established an open-ended ad hoc Intergovernmental Committee for the Cartagena Protocol on Biosafety (ICCP) with a mandate to undertake the preparations necessary for the first meeting of the Parties to the Protocol.

The ICCP Process

Following its establishment, the Intergovernmental Committee for the Cartagena Protocol on Biosafety (ICCP) convened an organisational meeting on 29 January 2000, chaired by Ambassador Yang, and endorsed the nominations of regional representatives to its Bureau. These included Cameroon (Chair), Denmark, India, Islamic Republic of Iran, Peru, Poland, Saint Kitts and Nevis, South Africa, Switzerland and Ukraine. At the first meeting of ICCP, Denmark was replaced by France. The ICCP Bureau held more than 10 oversight meetings over a period of four years of its existence. The first task of the Bureau was to develop a work plan for the ICCP which was submitted, to and endorsed by, the fifth meeting of the Conference of the Parties.

The ICCP held three meetings during the course of its existence. The first meeting was held in Montpellier, France, from 11 to 15 December 2000; the second in Nairobi, Kenya, 1 to 5 October 2001; and the third in The Hague, The Netherlands, and 22 to 26 April 2002 back to back with the sixth meeting of the Conference of the Parties.

Text of the Protocol

The Parties to this Protocol,

Being Parties to the Convention on Biological Diversity, hereinafter referred to as "the Convention", Recalling Article 19, paragraphs 3 and 4, and Articles 8 (g) and 17 of the Convention,

Recalling also decision II/5 of 17 November 1995 of the Conference of the Parties to the Convention to develop a Protocol on biosafety, specifically focusing on transboundary movement of any living modified organism resulting from modern biotechnology that may have adverse effect on the conservation and sustainable use of biological diversity, setting out for consideration, in particular, appropriate procedures for advance informed agreement,

Reaffirming the precautionary approach contained in Principle 15 of the Rio Declaration oh Environment and Development,

Aware of the rapid expansion of modern biotechnology and the growing public concern over its potential adverse effects on biological diversity, taking also into account risks to human health,

Recognising that modern biotechnology has great potential for human well-being if developed and used with adequate safety measures for the environment and human health,

Recognising also the crucial importance to humankind of centres of origin and centres of genetic diversity,

Taking into account the limited capabilities of many countries, particularly developing countries, to cope with the nature and scale of known and potential risks associated with living modified organisms.

Recognising that trade and environment agreements should be mutually supportive with a view to achieving sustainable development,

Emphasising that this Protocol shall not be interpreted as implying a change in the rights and obligations of a Party under any existing international agreements,

Understanding that the above recital is not intended to subordinate this Protocol to other international agreements,

Have agreed as follows:

Article I. Objective

In accordance with the precautionary approach contained in Principle 15 of the Rio Declaration-on Environment and Development, the objective of this Protocol is to contribute to ensuring an adequate level of protection in the field of the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, and specifically focusing on transboundary movements.

Article 2. General Provisions

1. Each Party shall take necessary and appropriate legal, administrative and other measures to implement its obligations under this Protocol.
2. The Parties shall ensure that the development, handling, transport, use, transfer and release of any living modified organisms are undertaken in a manner that prevents or reduces the risks to biological diversity, taking also into account risks to human health.
3. Nothing in this Protocol shall affect in any way the sovereignty of States over their territorial sea established in accordance with international law, and the sovereign rights and the jurisdiction which States have in their exclusive economic zones and their continental shelves in accordance with international law, and the exercise by ships and aircraft of all States of navigational rights and freedoms as provided for in international law and as reflected in relevant international instruments.
4. Nothing in this Protocol shall be interpreted as restricting the right of a Party to take action that is more protective of the conservation and sustainable use of biological diversity than that called for in this Protocol, provided that such action is consistent with the objective and the provisions of this Protocol and is in accordance with that Party's other obligations under international law.
5. The Parties are encouraged to take into account, as appropriate, available expertise, instruments and work undertaken in international forums with competence in the area of risks to human health.

Article 3. Use of Terms

For the purposes of this Protocol:

1. "Conference of the Parties" means the Conference of the Parties to the Convention;
2. "Contained use" means any operation, undertaken within a facility, installation or other physical structure, which involves living modified organisms that are controlled by specific measures that effectively limit their contact with; and their impact on, the external environment;
3. "Export" means intentional transboundary movement from one Party to another Party;
4. "Exporter" means any legal or natural person, under the jurisdiction of the Party of export, who arranges for a living modified organism to be exported;
5. "Import" means intentional transboundary movement into one Party from another Party;
6. "Importer" means any legal or natural person, under the jurisdiction of the Party of import, who arranges for a living modified organism to be imported;

7. "Living modified organism" means any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology;
8. "Living organism" means any biological entity capable of transferring or replicating genetic material, including sterile organisms, viruses and viroids;
9. "Modern biotechnology" means the application of:
   - **a.** In vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles, or
   - **b.** Fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection;
10. "Regional economic integration organisation" means an organisation constituted by sovereign-States of a given region, to which its member States have transferred competence in respect of matters governed by this Protocol and which has been duly authorised, in accordance with its internal procedures, to sign, ratify, accept, approve or accede to it;
11. "Transboundary movement" means the movement of a living modified organism from one Party to another Party, save that for the purposes of Articles 17 and 24 transboundary movements extend to movement between Parties and non-Parties.

Article 4. Scope

This Protocol shall apply to the transboundary movement, transit, handling and use of all living modified organisms that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health.

Article 5. Pharmaceuticals

Notwithstanding Article 4 and without prejudice to any right of a Party to subject all living modified organisms to risk assessment prior to the making of decisions on import, this Protocol shall not apply to the transboundary movement of living modified organisms which are pharmaceuticals for humans that are addressed by other relevant international agreements or organisations.

Article 6. Transit and Contained Use

1. Notwithstanding Article 4 and without prejudice to any right of a Party of transit to regulate the transport of living modified organisms through its territory and make available to the Biosafety Clearing-House, any decision of that Party, subject to Article 2, paragraph 3, regarding the transit through its territory of a specific living modified

organism, the provisions of this Protocol with respect to the advance informed agreement procedure shall not apply to living modified organisms in transit.

2. Notwithstanding Article 4 and without prejudice to any right of a Party to subject all living modified organisms to risk assessment prior to decisions on import and to set standards for contained use within its jurisdiction, the provisions of this Protocol with respect to the advance informed agreement procedure shall not apply to the transboundary movement of living modified organisms destined for contained use undertaken in accordance with the standards of the Party of import.

Article 7. Application Of The Advance Informed Agreement Procedure

1. Subject to Articles 5 and 6, the advance informed agreement procedure in Articles 8 to 10 and 12 shall apply prior to the first intentional transboundary movement of Jiving modified organisms for intentional introduction into the environment of the Party of import.
2. "Intentional introduction into the environment" in paragraph 1 above, does not refer to living modified organisms intended for direct use as food or feed, or for processing.
3. Article 11 shall apply prior to the first transboundary movement of living modified organisms intended for direct use as food or feed, or for processing.
4. The advance informed agreement procedure shall not apply to the intentional transboundary movement of living modified organisms identified in a decision of the Conference of the Parties serving as the meeting of the Parties to this Protocol as being not likely to have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health.

Article 8. Notification

1. The Party of export shall notify, or require the exporter to ensure notification to, in writing, the competent national authority of the Party of import prior to the intentional transboundary movement of a living modified organism that falls within the scope of- Article 7, paragraph 1. The notification shall contain, at a minimum, the information specified in Annex I.
2. The Party of export shall ensure that there is a legal requirement for the accuracy of information provided by the exporter.

Article 9. Acknowledgement of Receipt of Notification

1. The Party of import shall acknowledge receipt of the notification, in writing, to the notifier within ninety days of its receipt.
2. The acknowledgement shall state:

a. The date of receipt of the notification;
b. Whether the notification, prima facie, contains the information referred to in Articled;
c. Whether to proceed according to the domestic regulatory framework of the Party of import or according to the procedure specified in Article 10.

3. The domestic regulatory framework referred to in paragraph 2 (c) above, shall be consistent with this Protocol.
4. A failure by the Party of import to acknowledge receipt of a notification shall not imply its consent to an intentional transboundary movement.

Article 10. Decision Procedure

1. Decisions taken by the Party of import shall be in accordance with Article 15.
2. The Party of import shall, within the period of time referred to in Article 9, inform the notifier, in writing, whether the intentional transboundary movement may proceed:
   a. Only after the Party of import has given its written consent; or
   b. After no less than ninety days without a subsequent written consent.
3. Within two hundred and seventy days of the date of receipt of notification, the Party of import shall communicate, in writing, to the notifier and to the Biosafety Clearing-House the decision referred to in paragraph 2 (a) above:
   a. Approving the import, with or without conditions, including how the decision will apply to subsequent imports of the same living modified organism;
   b. Prohibiting the import;
   c. Requesting additional relevant information in accordance with its domestic regulatory framework or Annex I; in calculating the time within which the Party of import is to respond, the number of days it has to wait for additional relevant information shall not be taken into account; or
   d. Informing the notifier that the period specified in this paragraph is extended by a defined period of time.
4. Except in a case in which consent is unconditional, a decision under paragraph 3 above shall set out the reasons on which it is based.
5. A failure by the Party of import to communicate its decision within two hundred and seventy days of the date of receipt of the notification shall not imply its consent to an intentional transboundary movement.
6. Lack of scientific certainty due to insufficient relevant scientific information and knowledge regarding the extent of the potential adverse effects of a living modified

organism on the conservation and sustainable use of biological diversity in the Party of import, taking also into account risks to human health, shall not prevent that Party from taking a decision, as appropriate, with regard to the import of the living modified organism in question as referred to in paragraph 3 above, in order to avoid or minimise such potential adverse effects.

7. The Conference of the Parties serving as the meeting of the Parties shall, at its first meeting, decide upon appropriate procedures and mechanisms to facilitate decision-making by Parties of import.

Article 11. Procedure for Living Modified Organisms Intended for Direct Use as Food or Feed, or for Processing

1. A Party that makes a final decision regarding domestic use, including placing on the market, of a living modified organism that may be subject to transboundary movement for direct use as food or feed, or for processing shall, within fifteen days of making that decision, inform the Parties through the Biosafety Clearing-House. This information shall contain, at a minimum, the information specified in Annex II. The Party shall provide a copy of the information, in writing, to the national focal point of each Party that informs the Secretariat in advance that it does not have access to the Biosafety Clearing-House. This provision shall not apply to decisions regarding field trials.
2. The Party making a decision under paragraph 1 above, shall ensure that there is a legal requirement for the accuracy of information provided by the applicant.
3. Any Party may request additional information from the authority identified in paragraph (b) of Annex II.
4. A Party may take a decision on the import of living modified organisms intended for direct use as food or feed, or for processing, under its domestic regulatory framework that is consistent with the objective of this Protocol.
5. Each Party shall make available to the Biosafety Clearing-House copies of any national laws, regulations and guidelines applicable to the import of living modified organisms intended for direct use as food or feed, or for processing, if available.
6. A developing country Party or a Party with an economy in transition may, in the absence of the domestic regulatory framework referred to in paragraph 4 above, and in exercise of its domestic jurisdiction, declare through the Biosafety Clearing House that its decision prior to the first import of a living modified organism intended for direct use as food or feed, or for processing, on which information has been provided under paragraph 1 above, will be taken according to the following:

a. A risk assessment undertaken in accordance with Annex III; and

b. A decision made within a predictable timeframe, not exceeding two hundred and seventy days.

7. Failure by a Party to communicate its decision according to paragraph 6 above shall not imply its consent or refusal to the import of a living modified organism intended for direct use as food or feed, or for processing, unless otherwise specified by the Party.
8. Lack of scientific certainty due to insufficient relevant scientific information and knowledge regarding the extent of the potential adverse effects of a living modified organism on the conservation and sustainable use of biological diversity in the Party of import, taking also into account risks to human health, shall not prevent that Party from taking a decision, as appropriate, with regard to the import of that living modified organism intended for direct use as food or feed, or for processing, in order to avoid or minimise such potential adverse effects.
9. A Party may indicate its needs for financial and technical assistance and capacity-building with respect to living modified organisms intended for direct use as food or feed, or for processing. Parties shall cooperate to meet these needs in accordance with Articles 22 and 28.

Article 12. Review of Decisions

1. A Party of import may, at any time, in light of new scientific information on potential adverse effects on the conservation and sustainable use of biological diversity, taking also into account the risks to human health, review and change a decision regarding an intentional transboundary movement. In such case, the Party shall, within thirty days, inform any notifier that has previously notified movements of the living modified organism referred to in such decision, as well as the Biosafety Clearing-House, and shall set out the reasons for its decision.
2. A Party of export or a notifier may request the Party of import to review a decision it has made in respect of it under Article 10 where the Party of export or the notifier considers that:

   a. A change, in circumstances has occurred that may influence the outcome of the risk assessment upon which the decision was based; or

   b. Additional relevant scientific or technical information has become available.
3. The Party of import shall respond in writing to such a request within ninety days and set out the reasons for its decision.

4. The Party of import may at its discretion, require a risk assessment for subsequent imports.

Article 13. Simplified Procedure

1. A Party of import may, provided that adequate measures are applied to ensure the safe intentional transboundary movement of living modified organisms in accordance with the objective of this Protocol, specify in advance to the Biosafety Clearing-House:
   - **a.** Cases in which intentional transboundary movement to it may take place at the same time as the movement is notified to the Party of import; and
   - **b.** Imports of living modified organisms to it to be exempted from the advance informed agreement procedure.

   Notifications under subparagraph (a) above, may apply to subsequent similar movements to the same Party.
2. The information relating to an intentional transboundary movement that is to be provided in the notifications referred to in paragraph 1 (a) above, shall be the information specified in Annex I.

Article 14. Bilateral, Regional and Multilateral Agreements And Arrangements

1. Parties may enter into bilateral, regional and multilateral agreements and arrangements regarding intentional transboundary movements of living modified organisms, consistent with the objective of this Protocol and provided that such agreements and arrangements do not result in a lower level of protection than that provided for by the Protocol.
2. The Parties shall inform each other, through the Biosafety Clearing-House, of any such bilateral, regional and multilateral agreements and arrangements that they have entered into before or after the date of entry into force of this Protocol.
3. The provisions of this Protocol shall not affect intentional transboundary movements that take place pursuant to such agreements and arrangements as between the parties to those agreements or arrangements.
4. Any Party may determine that its domestic regulations shall apply with respect to specific imports to it and shall notify the Biosafety Clearing-House of its decision.

Article I5. Risk Assessment

1. Risk assessments undertaken pursuant to this Protocol shall be carried out in a scientifically sound manner, in accordance with Annex III and taking into account recognised risk assessment techniques. Such risk assessments shall be based, at a minimum, on information provided in accordance with Article 8 and other available scientific evidence in order to identify and evaluate the possible adverse effects of living

modified organisms on the conservation and sustainable use of biological diversity, taking also into account risks to human health.

2. The Party of import shall ensure that risk assessments are carried out for decisions taken under Article 10. It may require the exporter to carry out the risk assessment.
3. The cost of risk assessment shall be borne by the notifter if the Party of import so requires.

Article 16. Risk Management

1. The Parties shall, taking into account Article 8 (g) of the Convention, establish and maintain appropriate mechanisms, measures and strategies to regulate, manage and control risks identified in the risk assessment provisions of this Protocol associated with the use, handling and transboundary movement of living modified organisms.
2. Measures based on risk assessment shall be imposed to the extent necessary to prevent adverse effects of the living modified organism on the conservation and sustainable use of biological diversity, taking also into account risks to human health, within the territory of the Party of import.
3. Each Party shall take appropriate measures to prevent unintentional transboundary movements of living .modified organisms, including such measures as requiring a risk assessment to be carried out prior to the first release of a living modified organism.
4. Without prejudice to paragraph 2 above, each Party shall endeavour to ensure that any living modified organism, whether imported or locally developed, has undergone an appropriate period of observation that is commensurate with its life-cycle or generation time before it is put to its intended use.
5. Parties shall cooperate with a view to:
   a. Identifying living modified organisms or specific traits of living modified organisms that may have adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health; and
   b. Taking appropriate measures regarding the treatment of such living modified organisms or specific traits.

Article 17. Unintentional Transboundary Movements and Emergency Measures

1. Each Party shall take appropriate measures to notify affected or potentially affected States, the Biosafety Clearing-House and, where appropriate, relevant international organisations, when it knows of an occurrence under its jurisdiction resulting in a release that leads, or may lead, to an unintentional transboundary movement of a living modified organism that is likely to have significant adverse effects on the conservation and

sustainable use of biological diversity, taking also into account risks to human health in such States. The notification shall be provided as soon as the Party knows of the above situation.

2. Each Party shall, no later than the date of entry into force of this Protocol for it, make available to the Biosafety Clearing House the relevant details setting out its point of contact for the purposes of receiving notifications under this Article.
3. Any notification arising from paragraph 1 above should include:
    - **a.** Available relevant information on the estimated quantities and relevant characteristics and/or traits of the living modified organism;
    - **b.** Information on the circumstances and estimated date of the release, arid on the use of the living modified organism in the originating Party;
    - **c.** Any available information about the possible adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, as well as available information about possible risk management measures;
    - **d.** Any other relevant information; and
    - **e.** A point of contact for further information.
4. In order to minimise any significant adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, each Party, under whose jurisdiction the release of the living modified organism referred to in paragraph 1 above, occurs, shall immediately-consult the affected or potentially affected States to enable them to determine appropriate responses and initiate necessary action, including emergency measures.

Article 18. Handling, Transport, Packaging and Identification

1. In order to avoid adverse effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health, each Party shall take necessary measures to require that living modified organisms that are subject to intentional transboundary movement within .the scope of this Protocol are handled, packaged and transported under conditions of safety, taking into consideration relevant international rules and standards.
2. Each Party shall take measures to require that documentation accompanying:
    - **a.** Living modified organisms that are intended for direct use as food or feed, or for processing, clearly identifies that they "may contain" living modified organisms and are not intended for intentional introduction into the environment, as well as a contact point for further information. The Conference of the Parties serving as the meeting of

the Parties to this Protocol shall take a decision on the detailed requirements for this purpose, including specification of their identity and any unique identification, no later than two years after the date of entry into force of this Protocol;

b. Living modified organisms that are destined for contained use clearly identifies them as living modified organisms; and specifies any requirements for the safe handling, storage, transport and use, the contact point for further information, including the name and address of the individual and institution to whom the living modified organisms are consigned; and

c. Living modified organisms that are intended for intentional introduction into the environment of the Parry of import and any other living modified organisms within the scope of the Protocol, clearly identifies them as living modified organisms; specifies the identity and relevant traits and/or characteristics, any requirements for the safe handling, storage, transport and use, the contact point for further information and, as appropriate, the name and address of the importer and exporter; and contains a declaration that the movement is in conformity with the requirements of this Protocol applicable to the exporter.

3. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall consider the need for and modalities of developing standards with regard to identification, handling, packaging and transport practices, in consultation with other relevant international bodies.

Article 19. Competent National Authorities and National Focal Points

1. Each Party shall designate one national focal point to be responsible on its behalf for liaison with the Secretariat. Each Party shall also designate one or more competent national authorities, which shall be responsible for performing the administrative function required by this Protocol and which shall be authorised to act on its behalf with respect to those functions. A Party may designate a single entity to fulfil the functions of both focal point and competent national authority.
2. Each Party shall, no later than the date of entry into force of this Protocol for it, notify the Secretariat of the names and addresses of its focal point and its competent national authority or authorities. Where a Party designates more than one competent national authority, it shall convey to the Secretariat, with its notification thereof, relevant information on the respective responsibilities of those authorities. Where applicable, such information shall, at a minimum, specify which competent authority is responsible for which type of living modified organism. Each Party shall forthwith notify the Secretariat

of any changes in the designation of its national focal point or in the name and address or responsibilities of its competent national authority or authorities.

3. The Secretariat shall forthwith inform the Parties of the notifications it receives under paragraph 2 above, and shall also make such information available through the Biosafety Clearing House.

Article 20. Information Sharing and the Biosafety Clearing-House

1. A Biosafety Clearing-House is hereby established as part of the clearing-house mechanism under Article 18, paragraph 3, of the Convention, in order to:
   a. Facilitate the exchange of scientific, technical, environmental and legal information on, and experience with, living modified organisms; and
   b. Assist Parties to implement the Protocol, taking into account the special needs of developing country Parties, in particular the least developed and small island developing States among them, and countries with economies in. transition as .well as countries that are centres of origin and centres of genetic diversity.
2. The Biosafety Clearing-House shall serve as a means through which information is made available for the purposes of paragraph 1 above. It shall provide access to information made available by the Parties relevant to the implementation of the Protocol. It shall also provide access, where possible, to other international biosafety information exchange mechanisms.
3. Without prejudice to the protection of confidential information, each Party shall make available to the Biosafety Clearing-House any information required to be made available to the Biosafety Clearing-House under this Protocol, and:
   a. Any existing laws, regulations and guidelines for implementation of the Protocol, as well as information required by the Parties for the advance informed agreement procedure;
   b. Any bilateral, regional and multilateral agreements and arrangements;
   c. Summaries of its risk assessments or environmental reviews of living modified organisms generated by its regulatory process, and carried out in accordance with Article 15, including, where appropriate, relevant information regarding products thereof, namely, processed materials that are of living modified organism origin, containing detectable novel combinations of replicable genetic material obtained through the use of modern biotechnology;
   d. Its final decisions regarding the importation or release of living modified organisms; and

   e. Reports submitted by it pursuant to Article 33, including those on implementation of the advance informed agreement procedure.

4. The modalities of the operation of the Biosafety Clearing-House, including reports on its activities, shall be considered and decided upon by the Conference of the Parties serving as the meeting of the Parties to this Protocol at its first meeting, and kept under review thereafter.

Article 21. Confidential Information

1. The Party of import shall permit the notifier to identify information submitted under the procedures of this Protocol or required by the Party of import as part of the advance informed agreement procedure of the Protocol that is to be treated as confidential. Justification shall be given in such cases upon request.
2. The Party of import shall consult the notifier if it decides that information identified by the notifier as confidential does not qualify for such treatment and shall, prior to any disclosure, inform the notifier of its decision, providing reasons on request, as well as an opportunity for consultation and for an internal review of the decision prior to disclosure.
3. Each Party shall protect confidential information received under this Protocol, including any confidential information received in the context of the advance informed agreement procedure of the Protocol. Each Party shall ensure that it be procedures to protect such information and shall protect the confidentiality of such information in a manner no less favourable than its treatment of confidential information in connection with domestically produced living modified organisms.
4. The Party of import shall not use such information for a commercial purpose, except with the written consent of the notifier.
5. If a notifier withdraws or has withdrawn a notification, the Party of import shall respect the confidentiality of commercial and industrial information, including research and development information as well as information on which the Party and the notifier disagree as to its confidentiality.
6. Without prejudice to paragraph 5 above, the following information shall not be considered confidential:
   a. The name and address of the notifier;
   b. A general description of the living modified organism or organisms;
   c. A summary of the risk assessment of the effects on the conservation and sustainable use of biological diversity, taking also into account risks to human health; and
   d. Any methods and plans for emergency response.

Article 22. Capacity-Building

1. The Parties shall cooperate in the development and/or strengthening of human resources and institutional capacities in biosafety, including biotechnology to the extent that it is required for biosafety, for the purpose of the effective implementation of this Protocol, in developing country Parties, in particular the least developed and small island developing States among them, and in Parties with economies in transition, including through existing global, regional, subregional and national institutions and organisations and, as appropriate, through facilitating private sector involvement.
2. For the purposes of implementing paragraph 1 above, in relation to cooperation, the needs of developing country Parties, in particular the least developed and small island developing States among them, for financial resources and access to and transfer of technology and know-how in accordance with, the relevant provisions of the Convention, shall be taken fully into account for capacity-building in biosafety. Cooperation in capacity-building shall, subject to the different situation, capabilities and requirements of each Party, include scientific and technical training in the proper and safe management of biotechnology, and in the use of risk assessment and risk management for biosafety, and the enhancement of technological and institutional capacities in biosafety. The needs of Parties with economies in transition shall also be taken fully into account for such capacity-building in biosafety.

Article 23. Public Awareness and Participation

1. The Parties shall:
   a. Promote and facilitate public awareness, education and participation concerning the safe transfer, handling and use of living modified organisms in relation to the conservation and sustainable use of biological diversity, taking also into account risks to human health. In doing so, the Parties shall cooperate, as appropriate, with other States and international bodies;
   b. Endeavour to ensure that public awareness and education encompass access to information on living modified organisms identified in accordance with this Protocol that may be imported.
2. The Parties shall, in accordance with their respective laws and regulations, consult the public in the decision-making process regarding living modified organisms and shall make the results of such decisions available to the public, while respecting confidential information in accordance with Article 21.

3. Each Party shall endeavour to inform its public about the means of public access to the Biosafety Clearing-House.

Article 24. Non-Parties

1. Transboundary movements of living modified organisms between Parties and non-Parties shall be consistent with the objective of this Protocol. The Parties may enter into bilateral, regional and multilateral agreements and arrangements with non-Parties regarding such transboundary movements.
2. The Parties shall encourage non-Parties to adhere to this Protocol and to contribute appropriate information to the Biosafety Clearing-House on living modified organisms released in, or moved into or out of, areas within their national jurisdictions.

Article 25. Illegal Transboundary Movements

1. Each Party shall adopt appropriate domestic measures aimed at preventing and, if appropriate, penalising transboundary movements, of living modified organisms carried out in contravention of its domestic measures to implement this Protocol. Such movements shall be deemed illegal transboundary movements.
2. In the case of an illegal transboundary movement, the affected Party may request the Party of origin to dispose, at its own expense, of the living modified organism in question by repatriation or destruction, as appropriate.
3. Each Party shall make available to the Biosafety Clearing-House information concerning cases of illegal transboundary movements pertaining to it.

Article 26. Socio-Economic Considerations

1. The Parties, in reaching a decision on import under this Protocol or under its domestic measures implementing the Protocol, may take into account, consistent with their international obligations, socio-economic considerations arising from the impact of living modified organisms on the conservation and sustainable use of biological diversity, especially with regard to the value of biological diversity to indigenous and local communities.
2. The Parties are encouraged to cooperate on research and information exchange on any socioeconomic impacts of living modified organisms, especially on indigenous and local communities.

Article 27. Liability and Redress

The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first meeting, adopt a process with respect to the appropriate elaboration of international rules and procedures in the field of liability and redress for damage resulting from transboundary movements of living modified organisms, analysing and taking due account of the ongoing processes in international law on these matters, and shall endeavor to complete this process within four years.

Article 28. Financial Mechanism and Resources

1. In considering financial resources for the implementation of this Protocol, the Parties shall take into account the provisions of Article 20 of the Convention.
2. The financial mechanism established in Article 21 of the Convention shall, through the institutional structure entrusted with its operation, be the financial mechanism for this Protocol.
3. Regarding the capacity-building referred to in Article 22 of this Protocol, the Conference of the Parties serving as the meeting of the Parties to this Protocol, in providing guidance with respect to the financial mechanism referred to in paragraph 2 above, for consideration by the Conference of the Parties, shall take into account the need for financial resources by developing country Parties, in particular the least developed and the small island developing States among them.
4. In the context of paragraph 1 above, the Parties shall also take into account the needs of the developing country Parties, in particular the least developed and the small island developing States among them, and of the Parties with economies in transition, in their efforts to identify and implement their capacity-building requirements for the purposes of the implementation of this Protocol.
5. The guidance to the financial mechanism of the Convention in relevant decisions of the Conference of the Parties, including those agreed before the adoption of this Protocol, shall apply mutatis mutandis, to the provisions of this Article.
6. The developed country Parties may also provide, and the developing country Parties and the Parties with economies in transition avail themselves of, financial and technological resources for the implementation of the provisions of this Protocol through bilateral, regional and multilateral channels.

Article 29. Conference of the Parties Serving as the Meeting of the Parties to this Protocol

1. The Conference of the Parties shall serve as the meeting of the Parties to this Protocol.
2. Parties to the Convention that are not Parties to this Protocol may participate as observers in the proceedings of any meeting of the Conference of the Parties serving as the meeting of the Parties to this Protocol. When the Conference of the Parties serves as the meeting of the Parties to this Protocol, decisions under this Protocol shall be .taken only by those that are Parties to it.

3. When the Conference of the Parties serves as the meeting of the Parties to this Protocol, any member of the bureau of the Conference of the Parties representing a Party to the Convention but, at that time, not a Party to this Protocol, shall be substituted by a member to be elected by and from among the Parties to this Protocol.
4. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall keep under regular review the implementation of this Protocol and shall make, within its mandate, the decisions necessary to promote its effective implementation. It shall perform the functions assigned to it by this Protocol and shall:
   a. Make recommendations on any matters necessary for the implementation of this Protocol;
   b. Establish such subsidiary bodies as are deemed necessary for the implementation of this Protocol;
   c. Seek and utilise, where appropriate, the servicers and cooperation of, and information provided by, competent international organisations and intergovernmental and non-governmental bodies;
   d. Establish the form and the intervals for transmitting the information to be submitted in accordance with Article 33 of this Protocol and consider such information as well as reports submitted by any subsidiary body;
   e. Consider and adopt, as required, amendments to this Protocol and its annexes, as well as any additional annexes to this Protocol, that are deemed necessary for the implementation of this Protocol; and
   f. Exercise such other functions as may be required for the implementation of this Protocol.
5. The rules of procedure of the Conference of the Parties and financial rules of the Convention shall be applied, mutatis mutandis, under this Protocol, except as may be otherwise decided by consensus by the Conference of the Parties serving as the meeting of the Parties to this Protocol.
6. The first meeting of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be convened by the Secretariat in conjunction with the first meeting of the Conference of the Parties that is scheduled after the date of the entry into force of this Protocol. Subsequent ordinary meetings of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be held in conjunction with ordinary meetings of the Conference of the Parties, unless otherwise decided by the Conference of the Parties serving as the meeting of the Parties to this Protocol.

7. Extraordinary meetings of the Conference of the Parties serving as the meeting of the Parties to this Protocol shall be held at such other times as may be deemed necessary by the Conference of the Parties serving as the meeting of the Parties to this Protocol, or at the written request of any Party, provided that, within six months of the request being communicated to the Parties by the Secretariat, it is supported by at least one third of the Parties.
8. The United Nations, its specialised agencies and the International Atomic Energy Agency, as well as any State member thereof or observers thereto not party to the. Convention may be represented as observers at meetings of the Conference of the Parties serving as the meeting of the Parties to this Protocol. Anybody or agency, whether national or international, governmental or non-governmental, that is qualified in matters covered by this Protocol and that has informed the Secretariat of its wish to be represented at a meeting of the Conference of the Parties serving as a meeting of the Parties to this Protocol as an observer, may be so admitted, unless at least one third of the Parties present object. Except as otherwise provided in this Article, the admission and participation of observers shall be subject to the rules of procedure, as referred to in paragraph 5 above.

Article 30. Subsidiary Bodies

1. Any subsidiary body established by or under the Convention may, upon a decision by the Conference of the Parties serving as the meeting of the Parties to this Protocol, serve the Protocol, in which case the meeting of the Parties shall specify which functions that body shall exercise.
2. Parties to the Convention that are not Parties to this Protocol may participate as observers in the proceedings of any meeting of any such subsidiary bodies. When a subsidiary body of the Convention serves as a subsidiary body, to this Protocol, decisions under the Protocol shall be taken only by the Parties to the Protocol.
3. When a subsidiary body of the Convention exercises its functions with regard to matters concerning this Protocol, any member of the bureau of that subsidiary body representing a Party to the Convention but, at that time, not a Party to the Protocol, shall be substituted by a member to be elected by and from among the Parties to the Protocol.

Article 31. Secretariat

1. The Secretariat established by Article 24 of the Convention shall serve as the secretariat to this Protocol.

2. Article 24, paragraph 1, of the Convention on the functions of the Secretariat shall apply, mutatis mutandis', to this Protocol.
3. To the extent that they are distinct, the costs of the secretariat services for this Protocol shall be met by the-Parties hereto. The Conference of the Parties' serving as the meeting of the Parties to this Protocol shall, at its first meeting, decide on the necessary budgetary arrangements to this end.

Article 32. Relationship with The Convention

Except as otherwise provided in this Protocol, the provisions of the Convention relating to its protocols shall apply to this Protocol.

Article 33. Monitoring and Reporting

Each Party shall monitor the implementation of its obligations-under this Protocol, and shall, at intervals to be determined by the Conference of the Parties serving as the meeting of the Parties to this Protocol, report to the Conference of the Parties serving as the meeting of the Parties to this Protocol on measures that it has taken to implement the Protocol.

Article 34. Compliance

The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first meeting, consider and approve cooperative procedures and institutional mechanisms to promote compliance with the provisions of this Protocol and to address cases of non-compliance. These procedures and mechanisms shall include provisions to offer advice or assistance, where appropriate. They shall be separate from, and without prejudice to, the dispute settlement procedures and mechanisms established by Article 27 of the Convention.

Article 35. Assessment and Review

The Conference of the Parties serving as the meeting of the Parties **to** this Protocol shall undertake, five years after the entry into force of this Protocol and at least every five years thereafter, an evaluation of the effectiveness of the Protocol, including an assessment of its procedures and annexes.

Article 36. Signature

This Protocol shall be open for signature at the United Nations Office at Nairobi by States and regional economic integration organisations from 15 to 26 May 2000, and at United Nations Headquarters in New York from 5 June 2000 to 4 June 2001.

Article 37. Entry into Force

1. This Protocol shall enter into force on the ninetieth day after the date of deposit of the fiftieth instrument of ratification, acceptance, approval or accession by States or regional economic integration organisations that are Parties to the Convention.

2. This Protocol shall enter into force for a State or regional economic integration organisation that ratifies, accepts or approves this Protocol or accedes thereto after its entry into force pursuant to paragraph 1 above, on the ninetieth day after the date on which that State or regional economic integration organisation deposits its instrument of ratification, acceptance, approval or accession, or on the date on which the Convention enters into force for that State or regional economic integration organisation, whichever shall be the later.
3. For the purposes of paragraphs 1 and 2 above, any instrument deposited by a regional economic integration organization shall not be counted as additional to those deposited by member States of such organisation.

Article 38. Reservations

No reservations may be made to this Protocol.

Article 39. Withdrawal

At any time after two years from the date on which this Protocol has entered into force for a Party that Party may withdraw from the Protocol by giving written notification to the Depositary. 2. Any such withdrawal shall take place upon expiry of one year after the date of its receipt by the Depositary, or on such later date as may be specified in the notification of the withdrawal.

Article 40. Authentic Texts

The original of this Protocol, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations.

In Witness Whereof the undersigned, being duly authorised to that effect, have signed this Protocol. Done at Montreal on this twenty-ninth day of January, two thousand.

Annex I. Information Required In Notifications under Articles 8, 10 And 13

a. Name, address and contacT details of the exporter
b. Name, address and contact details of the importer,
c. Name and identity of the living modified organism, as well as the domestic classification, if any, of the biosafety level of the living modified organism in the State of export.
d. Intended date or dates of the transboundary movement, if known.
e. Taxonomic status, common name, point of collection or acquisition, and characteristics of recipient organism or parental organisms related to biosafety.

f. Centres of origin and centres of genetic diversity, if known, of the recipient organism and/or the parental organisms and a description of the habitats where the organisms may persist or proliferate.

g. Taxonomic status, common name, point of collection or acquisition, and characteristics of the donor organism or organisms related to Biosafety.

h. Description of the nucleic acid or the modification introduced, the technique used, and the resulting characteristics of the living modified, organism.

i. Intended use of the living modified organism or products thereof, namely, processed materials that are of living modified" organism origin, containing detectable novel combinations of replicable genetic material obtained through the use .of modern biotechnology.

j. Quantity or volume of the living modified organism to be transferred.

k. A previous and existing risk assessment report consistent with Annex III.

l. Suggested methods for the safe handling, storage, transport and use, including packaging, labelling, documentation, disposal and contingency procedures, where appropriate.

m. Regulatory status of the living modified organism within the State of export (for example, whether it is prohibited in the State of export, whether there are other restrictions, or whether it has been approved for general release) and, if the living modified organism is banned in the State of export, the reason or reasons for the ban.

n. Result and purpose of any notification by the exporter to other states regarding the living modified organism to be transferred.

o. A declaration that the above-mentioned information is factually correct.

Annex II. Information Required Concerning Living Modified Organisms Intended For Direct Use as Food Or Feed, Or For Processing Under Article II

a. The name and contact details of the applicant for a decision for domestic use.

b. The name and contact details of the authority responsible for the decision.

c. Name and identity of the living modified organism.

d. Description of the gene modification, the technique used, and the resulting characteristics of the living modified organism.

e. Any unique identification of the living modified organism.

f. Taxonomic status, common name, point of collection or acquisition, and characteristics of recipient organism or parental organisms related to biosafety.

g. Centres of origin and centres of genetic diversity, if known, of the recipient organism and/or the parental organisms and a description of the habitats where the organisms may persist or proliferate.
h. Taxonomic status, common name, point of collection oracquisition, and characteristics of the donor organism or organisms related to biosafety.
i. Approved uses of the living modified organism.
j. A risk assessment report consistent with Annex III.
k. Suggested methods for the safe handling, storage, transport and use, including packaging, labelling, documentation, disposal and contingency procedures, where appropriate.

Annex III, Risk Assessment

Objective

The objective of risk assessment under this Protocol is to identify and evaluate the potential adverse effects of living modified organisms on the conservation and sustainable use of biological diversity in the likely potential receiving environment, taking also into account risks to human health.

Use of risk assessment

Risk assessment is, inter alia, used by competent authorities to make informed decisions regarding living modified organisms.

General principles

Risk assessment should be carried out in a scientifically sound and transparent manner, and can take into account expert advice of, and guidelines developed by, relevant international organisations.

1. Lack of scientific knowledge or scientific consensus should not necessarily be interpreted as indicating a particular level of risk, an absence of risk, or an acceptable risk.
2. Risks associated with living modified organisms or products thereof, namely, processed materials that are of living modified organism origin, containing detectable novel combinations of replicable genetic material obtained- through the use of modern biotechnology, should be considered in the context of the risks posed by the non-modified recipients, or parental organisms in the likely potential receiving environment.
3. Risk assessment should be carried out on a case-by-case basis. The required information may vary in nature and level of detail from case to case, depending on the living modified organism concerned, its intended use and the likely potential receiving environment.

Methodology

The process of risk assessment may on the one hand give rise to a need for further information about specific subjects, which may be identified and requested during the assessment process, while on the other hand information on other subjects may not be relevant in some instances.

To fulfil its objective, risk assessment entails, as appropriate, the following steps:

a. An identification of any novel genotypic and phenotypic characteristics associated with the living modified organism that may have adverse effects on biological diversity in the likely potential receiving environment, taking also into account risks to human health;
b. An evaluation of the likelihood of these adverse effects being realised, taking into account the level and kind of exposure of the likely potential receiving environment to the living modified organism;
c. An evaluation of the consequences should these adverse effects be realised;
d. An estimation of the overall risk posed by the living modified organism based on the evaluation of the likelihood and consequences of the identified adverse effects being realised;
e. A recommendation as to whether or not the risks are acceptable or manageable, including, where necessary, identification of strategies to manage these risks; and
f. Where there is uncertainty regarding the level of risk, it may be addressed by requesting further information on the specific issues of concern or by implementing appropriate risk management strategies and/or monitoring the living modified organism in the receiving environment.

Points to consider

Depending on the case, risk assessment takes into account the relevant technical and scientific details regarding the xharaeterlstics,15 of the following subjects:

a. Recipient organism or parental organisms. The biological characteristics of the recipient organism or parental organisms, including information on taxonomic status, common name, origin, centres of origin and centres of genetic diversity, if known, and a description of the habitat where the organisms may persist or proliferate:
b. Donor organism or organisms. Taxonomic status and common name, source, and the relevant biological characteristics of the donor organisms;
c. Vector. Characteristics of the vector, including its identity, if any, and its source or origin, and its host range;

d. Insert or inserts and/or characteristics of modification. Genetic characteristics of the inserted nucleic acid and the function it specifies, and/or characteristics of the modification introduced;
e. Living modified organism. Identity of the living modified organism, and the differences between the biological characteristics of the living modified organism and those of the recipient organism or. parental organisms;
f. Detection and identification of the living modified organism. Suggested detection and identification methods and their specificity, sensitivity and reliability;
g. Information relating to the intended use. Information relating to the intended use of the living modified organism, including new or changed use compared to the recipient organism or parental organisms; an
h. Receiving environment. Information -on the location, geographical, climatic and ecological characteristics, including relevant information on biological diversity and centres of origin of the likely potential receiving environment.

7 Bioprospecting

The Europeans had learned and benefited greatly from observations of how plants were used by indigenous peoples of the Old World much before the voyages of Columbus. The ancient Greeks and Arabs were importing large quantities of spices such as cassia *(Cinnamomum cassia)*, cinnamon *(Cinnamomum zeylanicum))*, cardamom *(Eletteria cardamomum)* etc. from the orient as early as the 5th century B.C. There existed a trans-Asian silk route during the 1st century A.D. that further facilitated trade in several items between the Old World and Europe. Today just the volatile oils of taxa mentioned above are worth more than US $7 million per annum to the countries that produce them. Besides these bioresources, indigenous knowledge of plants and microbes has hardly been tapped. Unfortunately hundreds and hundreds of-knowledgeable people have either died without divulging their knowledge on traditional food and medicinal plants or refuse to v part with it for reasons best known to them. This has resulted in the absence/scarcity of records or documentation of indigenous knowledge in mainly countries of the world. Unravelling such knowledge merits top priority. Hence it is not surprising that research today is mainly aimed at

1) Identifying novel plants and plant products that have untapped but substantial economic potential.
2) Popularising and modifying traditional techniques so as to conserve vulnerable taxa and habitats.
3) Conserving traditional germplasms of useful species and their wild relatives for further improvement programmes.

These three aspects are covered under Bioprospecting or Biodiversity prospecting.

Bioprospecting is also referred to as Gene Prospecting. Bioprospecting, in more common usage, is the exploration of biodiversity for ever valuable genetic and/or biochemical resource that finds use in pharmaceutical, biotechnological and agricultural industries either through bioprocesses unique to them or through novel end or by-products (Eisner, 1992; Reid, Laird *et al.*, 1993; Sittenberg and Gamez, 1993). Increased interest in bioprospecting is attributable to:

1) Decline in innovativeness in the chemical and pharmaceutical industries;
2) The rise on biotechnology as a dominant economic sector;
3) Concern over biodiversity loss;

4) The invigorated effort by developing countries to search for new economic activities; and above all.
5) Advances in the techniques for bioprospecting.

Recent biotechnological advances have strengthened the hands of scientists in analysing organisms at the molecular-genetic level and finding ways of producing commercially viable products and processes at enhanced quantities/qualities using genetically modified organisms. Expectations from these pew biotechnologies have further stimulated biodiversity, prospecting which, according to some, will in turn stimulate profit-motivated steps towards active conservation of bioresources (Joyce, 1994). However, one should not disregard the fact that in the absence of strict enforcement of legislation' and lack of suitable equitable, benefit-sharing mechanisms, this 'gene rush' will not only deteriorate our ecosystems (including their species), but also provide less, if any, benefit sharing to indigenous people—the real owners of such traditional biodiversity knowledge. One of the striking causalities of bioprospecting is. *Meytenus buchananni*, the important source of the anticancer compound.

Meytansine; its entire population was completely lost from Kenya in a single expedition by the National Cancer Institute, USA. Already several pharmaceutical multinationals are screening the plants of tropical forests of several developing countries, which are rich in biodiversity, such as Costa Rica, Brazil, India, Colombia, Chile, and Micronesia etc. Bioprospecting is also increasingly practiced in forest habitats of temperate countries and Hypothermal vents deep under the sea (UNEP 1995).

It is very difficult to correctly estimate the commercial value of bioprospecting in pharmacy, industry, agriculture, and forestry. Tables 6.1 to 6.3 provide some data on the approximate value of some traditional natural products exploited in very recent years. Companies that produce seeds and agrochemicals substantially benefit from the free flow of germplasms from traditional societies and the market value of seed germplasms using land races is estimated at $ 50 million per year in the US alone (RAFI 1994). For many more bioresources obtained from indigenous societies, the value has not been estimated to date but is definitely substantial. It should, however, be mentioned that to date only a small proportion of biodiversity has been exploited nevertheless there are sufficient indications that the economic potential of bioresources yet to be exploited is enormous. In view of the aforesaid, bioprospecting is rapidly growing into a new industry on its own merit.

Essentially three methods have been used until now in the choice and collection of plants for novel uses/compounds. The first is the random method, which involves the random collection of plants found in a given area of study for analysis of their economic potential. The second is the phylogenetic method, which involves the collection and analysis of all members of those plant families in which some taxa are already known to be good sources of useful products (e.g. Solanaceae). The third method, much superior to the first two, is the ethno-directed method. In this method, attention is particularly focused on plants which, based on traditional knowledge, are known to be used by tribal people/indigenous community, but not yet popularised. In other words, it is ready-made knowledge that is sure to yield the desired results in addition to involving less research and development costs; it is also less time-consuming. About three-quarters of the biologically active plant-derived compounds presently in Use globally have been discovered through follow-up research on folk and ethriomedicinal uses (see Cotton, 1996).

Indigenous Knowledge Systems

It is difficult to define indigenous people/ community'. The dictionary definition of indigenous' is residence in any area for a very long time. The widely acknowledged legal definition of 'indigenous people' is politically weak people/community belonging to a culturally distinct ethnic entity and having an identity different from the mainstream-national society and deriving subsistence from local resources. The World Bank additionally characterises them as a social group vulnerable to domination. International labor organisations as well as the CBD expect such person to self-identify themselves as indigenous, which entitles them to their lawful rights. According to the International Working Group on Indigenous affairs based at Copenhagen, there are approximately 300-500 'million indigenous people the world over. Nearly half live in India and China. The knowledge these people have accumulated over several hundreds of years is termed traditional or indigenous knowledge.

It should be clear from the foregoing that traditional indigenous knowledge concerning biodiversity is of paramount importance. Today, .traditional societies throughout the world possess a wealth of knowledge accumulated through trial and error for several hundreds of years during their prolonged and close interaction with Nature. Within a very short time after its inception, the science of biodiversity has become a very important tool in highlighting the Significance of Indigenous (= Traditional) Knowledge Systems (DCS or TKS). IKS is also known by many other terms such as TIK (Indigenous Technical Knowledge), IAK (Indigenous Agricultural Knowledge), RPK (Rural Peoples Knowledge), TBK (Traditional Botanical Knowledge), TEK (Traditional Ecological Knowledge) etc. (for more details, see Cotton 1996).

The IKS, in its most modern concept, includes all the information, knowledge, wisdom, practices, beliefs and philosophies of traditional societies built arid accumulated by members of these societies through several generations in close contact with Nature. The following are the important categories of IKS (Posey, 1997):

i. Sacred property (images, sounds, knowledge, material, culture) or anything considered sacred;
ii. Knowledge of present, past and future potential uses of biodiversity elements as well as of soils and minerals;
iii. Knowledge of preparations arid processes as well as of storage/ preservation of useful taxa;
iv. Knowledge of formulations involving more than one ingredient in food/ beverage/ medicine;

Know individual species, such as planting cultivation and harvesting of each knowledge of habitats and ecosystems; classificatory systems of knowledge, traditional taxonomies. Three broad categories TEK were identified by Inglis knowledge about the specific component environment such as plants, animals, social development, evolution and use of applied technologies for farming, forestry etc.; understanding the intimate relationship traditional societies with the environment whole.

Such knowledge is often difficult for western science to understand and appreciate. The sacred bondage between Nature and Society was recognised by UNESCO in its 1972 Convention on the Protection of the World Cultural and Natural Heritage, often called the World Heritage Conference, and a new category of World . Heritage Sites called 'Cultural Landscapes' was established (D.D. Posey 1997). Such an effort becomes all the more significant since the world's richest biodiversity areas, in terms of hot spots and megadiversity centres, have been maintained and defended by several diverse indigenous societies in the tropics as well as in temperate regions against destruction for all these years (Posey and Dutfield 1997); likewise the several land races of agricultural crops.

8 Biopiracy

The recognition of 'Cultural Landscapes' has very important implications for ownership and hence for Intellectual Property Rights (IPRs). Although wild species are products of nature and human societies can lay no special claim to them, any knowledge about them (including values) should logically be covered by an IPR. Moreover, many species/landscapes have been moulded / modified by indigenous societies who, therefore, are entitled to a special claim on them. This enlarges the implications of IPR for communities beyond the recognised categories of use, extraction, processing and preservation' (Posey, 1997). Since ethno-directed bioprospecting will significantly reduce research and development costs by using traditional knowledge extracted from IKS, loss of bits of such knowledge will lead to the traditional society's v losing control over information that has been theirs many years.

The existing mechanisms are also highly inadequate for effectively protecting the genuine rights of traditional societies (Posey, 1996; Posey and Dutfield, 1996, 1997). It is very sad to note that only a miniscule proportion of profits (often less than 0.001%) earned from bio products has been returned to the indigenous peoples from whom much of the knowledge was extracted (Posey, 1990). In several instances the indigenous society has received no return whatsoever. Only in recent years have a number of contracts have been set up between industrial organisations, academic researchers and traditional communities in biodiversity prospecting (Laird, 1993). One instance may be mentioned, namely the agreement reached between INBio, Costa Rica's National Biodiversity Institute, and the US-based Merck & Co. Ltd. This agreement provides US $1135 million to INBio from Merck for screening of the biodiversity elements of Costa Rica for prospective bioactive chemicals of economic potential, in addition to royalties. The royalties will be used by INBio to further its inventory and research and to support a fund for the management of Costa Rica's National Parks (Reideffl, 1993).

Biopiracy or 'gene robbing' may be defined as any effort by biodiversity prospectors to 'steal' or 'rob' traditional societies of their knowledge about biodiversity and use-that knowledge to earn money without reimbursement to the owner-society. Until recently the biotechnologically rich developed countries and multinational companies have proprietorially exploited the rich bioresources of developing countries through the powerful tool of gene technology. These prospectors assumed ecosystems and their components to be 'wild' and 'part of the common heritage of humankind' and, therefore, 'leads' provided by indigenous knowledge systems need not be covered under patent rules; based on such leads, the prospectors make 'protectable products or processes'. Such piracies have been brought to public attention in recent years through various organisations such as RAFI (Rural Advancement Foundation International) (RAFI, 1994). Cases of biopiracy are voluminous but only three classic examples are given below.

The Urueu-Wau-Wau tribe of the Amazon region has long used an anticoagulant called 'tiki uba' and this fact was published in 1989 in an article written by Mclntyre in a renowned magazine (Mclntyre, 1989). Based on this information, Merck Pharmaceuticals did further research and found that the extract of this plant was very helpful during heart surgery; the company subsequently patented its 'discovery' with no reference to the traditional knowledge provided by the Urueu-Wau-Wau tribe (Jacobs *et al.,*. 1990; Posey *et al.,* 1995).

Indian people have for centuries used various parts of the neem plant for several purposes, including protection of crops against diverse pests. They found through experience that neem products are not only environment-friendly but also cheap. The active component of neem, azadiractin, was patented by two USA companies W.R. Grace and Agrodyne Technologies with no acknowledgement whatsoever that the traditional knowledge system of the indigenous people of India led to the isolation of azadiractin. However, on 30th September 1997, the European patent office delivered a favorable judgment against the patent given to W.R. Grace &Co for using neem oil products as fungicides. This was due to the efforts of Indian NGOs who undertook the Neem Campaign.

The 'Endod' case is particularly interesting. Ethiopians have for countless years used the berries of endod, an indigenous African soap berry plant *(Phytolacca dodecandra),* as a detergent. It was later accidentally discovered that the mollusc carrying the pathogen causing the dreaded North African disease, schistosomiasis, was killed in streams where endod was used as a detergent. Ethiopian and Netherland scientists further collaborative research, identified the elite E-44 variety of this plant taxa and obtained lemmatoxin, the active chemical involved in killing the mollusks that harbours the pathogen. This was patented by the Netherland and Ethiopian scientists who worked on the project with no benefit given to the local people who had been aware of the knowledge for a very long time (Pos and Dutfieia, 1996,1997).

9 Intellectual Property Rights

Attention has already been drawn to the problem concerning protection of IKS by IPRs. Here intricacies of the problem are elaborated ways and means of solving them suggested. The three cases presented above and several other known of biopiracy raise the following two major issues (D.D. Posey 1997):

i. Indigenous people and societies cannot obtain legal protection for their traditional knowledge and resources- for various reasons (discussed below), which industries/academics somehow obtain legal rights for their application traditional knowledge and resources thus depriving the genuine beneficiary of any benefit.

ii. As already mentioned on page 186, to technologically poor but biodiversity rich countries of the world lack the capacity facilities and money to adequately exploited the commercial potential of the traditional knowledge or to defend knowledge from being usurped industries/academics of affluence countries.

As of today, IPRs are the main legal mechanisms available for protecting knowledge discoveries, innovations, inventions and practices. Patents are the best known of the IPRs. Patents, however, are of very limited value to most traditional people/societies as there are several difficulties in documenting such knowledge and in identifying the actual inventor or discoverer. In many instances, indigenous knowledge is considered in the 'public domain' and hence 'uniqueness' as required in Patent Rules also becomes problematic. In many traditional societies, even if technical requirements for patenting knowledge were satisfied, there are problems in meeting the costs of filing the Patent Papers, maintaining and monitoring their legal claims, and legal implementation and enforcement once protection is granted (Posey, 1997).

The other difficulties posed by IPRs to traditional societies are as follows (Posey, 1997):

a. IPRs benefit a society usually through the granting of rights to a small group/ individuals but not to the whole indigenous society.

b. IPRs can protect only information that results from a specific historic act of 'discovery', whereas traditional knowledge is passed on through- several generations; hence such knowledge falls in the 'public domain' and cannot be protected;

c. While the basic motive of IPRs is to-encourage commercialisation of knowledge and discovery, indigenous societies are not concerned with commercialisation; in fact, they prohibit it, thereby restricting the use of such knowledge to only within the society,

d. IPRs invariably recognise only market value, while indigenous knowledge is often linked to spiritual, aesthetic and cultural values; at best, local economic value (within the society) is recognised,

e. IPRs are expensive, complex in nature, and time-consuming to obtain and defend.

The UN conferences on Environment and Development and its Convention on Biological Diversity (CBD) have highlighted the importance of indigenous knowledge and the close dependence of traditional societies on bioreseurces. Article 8.j. of CBD addresses the different States of the world to 'respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities and encourage the equitable sharing of the benefits arising from the utilisation of such knowledge....' Article 18.4 of CBD, however characterises such knowledge as 'traditional and indigenous technologies and that those relevant to biodiversity should be transferred and used through the creation of a Clearing-House Mechanism (CHM) (Article 18.3).

CHM is problematic in the sense that if expects the use of technologies to be regulated by an IPR. On the other hand, indigenous societies point out the problems of existing IPRs listed above in protecting IKS, and are adamant that 'additional alternative or *sui generis* systems' should be created in place of IPRs to ensure their rights in profit-sharing. Unfortunately, the CBD provides no mechanism for protecting the rights of IKS (Posey, 1997). Also, under Article 27.3b, Section 5, of the TRIPS agreement States are allowed to make exemptions from the patenting of plants, if an effective *sui generis* protection system for plant varieties also exists (Leskien and Filtner 1997). Given the foregoing, traditional societies demand implementation of one of the following three proposals:

a. Modify the existing IPR to cover the previously unprotected IKS.
b. Formulate an entirely new IPR to protect IKS as well as the existing IPRs.
c. Propose an alternative to IPR that will exclusively cover IKS.

Most traditional societies favour the third proposal. A number of declarations to this effect have been made by indigenous and local communities. The most important are the Kari Oca Declaration, the Mataarua Declaration, the Santa Cruz Declaration, the Leficia Declaration and Plan and Action, the Treaty for Life Forms Patent Free Pacific, the UkupSeni Kuna Yala Declaration, the Jovel Declaration on Indigenous communities, the Chiapas Declaration etc.

Traditional Resource Rights (TRR)

TRR is a process that respects the requirements of the indigenous people; in addition, it favours the development of appropriate *sui generis* systems for protecting IKS. TRR is one of the two alternative ways of implementing the idea of benefit sharing, that is, the internalisation of existing or expected-benefits. TRR is considered more a process than a product. TRRs form around four processes (Posey, 1997):

1. Identification and expression of 'bundles of rights'. The 'bundles of rights' include human rights, rights to self-determination, land and terrestrial rights, right to development, environmental integrity rights, cultural heritage rights, IPRs, right to privacy, religious freedom etc.
2. Fast evolving 'soft law' primarily based on recognition of customary practice and legally non-binding agreements, declarations and covenants'. Traditional societies have their own system of justice with respect to sharing of knowledge and rights and responsibilities **a**ttached to possession of such knowledge.
3. Harmonisation' of all existing legally binding international agreements, by obtaining signatures of all States; the States should sign such agreements only after ascertaining that the agreements are compatible with the rights of their traditional societies.
4. 'Equitizing' to ensure a very effective participation of indigenous and traditional societies in all phases of the implementation process.

TRR-guided efforts can open up a conducive atmosphere for new partnerships based on increased respect for IKS. This would then enable every State to implement its international obligations on trade and sustainable development. In the long run, such efforts would also open up IKS on biodiversity for more biotechnological exploitations.

Local Efforts to Date

Indigenous societies have recently become better informed/organised and more articulate. Either they have started to assert their rights forcefully or have preferred to generate, control, distribute and use their knowledge through their own networks; databases arid organisations. They have also made their voices heard by the developed countries, which either lack or are very poor in IKS. There is also a growing alliance between indigenous people and those who profess environmentalism and biosafety. Thus the theory and practice of local participation in rural/tribal development have become well established. Several conservationists and NGOs have recently begun to vigorously utilise this concept. These activities have now come to be known as participatory approaches to biodiversity management and utilisation (Cohen and Uphof, 1977; Gadgil *et al*.,. 1993; Paul 1987; Salmen 1987). There are five major areas in which traditional societies and their people can participate: Information-gathering, consultation decision-making, initiating actions and evaluation. A few instances of local efforts towards participatory management are provided below.

Territorial Demarcation of Traditional Societies

The most important requirement for traditional societies is legal title to their lands and territories where they practice their own land-use patterns, watershed management, cultivation, forest management etc. Sacred groves, for example, are areas of cultural and botanical significance and so should be covered by legal acts. Many cultural landscapes are often very difficult to detect and so must be properly documented and mapped. Such an act would indicate to outsiders that these are not 'wild' but 'private' and protected.

Self-demarcation of traditional territories has already been followed by several indigenous societies across the world, for example the Ye'kuana in Venezuela.

Community Forest Management

In many parts of South and South-east Asia, communities ruled and regulated forests and their resources in the historic past, thus ensuring j equitable distribution of forest lands and products for agriculture, hunting and gathering of timber, fuel and minor forest produce.

However, in the last one to three hundred years the governance of forests has fallen into the hands of the government in. many countries. In the last two decades or so, empowerment of communities as protectors of forests has again come into operation, especially in India, in order to facilitate the sustainable maintenance of their productivity. The concept of Joint Forest Management has gained ground in India, Thailand and a few other oriental countries, with local communities becoming partners in protecting forest resources and in sharing the benefits. This was initially tried in West Bengal and encouraged by the success of this system there, other States in India felt encouraged to follow suit. There are now nearly 10,000'forest protection committees managed by participating communities and approximately two million hectares of forest are managed under Joint Forest Management. A recent study in Thailand has similarly revealed nearly 12,000 community forest management initiatives.

The Asian experience on forest management has highlighted the fact that elaborate policies and heavily funded projects are no longer needed to protect our forests.

Indigenous People and Protected Areas

People living in or near protected areas were earlier denied derivation of benefits from them soon after the areas were declared protected. However/it was soon felt that such people should be provided adequate means to continue to derive benefits from protected areas without affecting/degrading them. One such measure was to create buffer and core zones in the protected areas and allow the buffer zones to be used for sustainable exploitation of bioresources, leaving the core zone highly protected (Wells *et al.* 1992). In many cases economic incentives are often additionally provided to the local community to exclusively exploit the buffer zones.

Community Biodiversity Registers

This is a 'bottoms-up system' of recording data information on wild and domesticated biodiversity (Gadgil *et al.,* 1995). These have been developed in India in an effort to secure community control over TEK. People of traditional societies are encouraged to document all the known plant and animal species, with all available details on their uses. CBRs will contain four separate sections (Gadgil *et al.*, 1995):

1. Background information: This will cover two modules. Module 1 will delineate the total land and water areas, settlements and human communities. Module 2 will cover the local ecological history, which will include accounts of major changes that affect(ed) the landscape and waterscape elements, people, cultivate crops, livestock etc. the driving factors behind these major changes, and the establishment of 'Historical Benchmarks' (such as famine, year of completion of a dam etc). As part of this effort, sufficient awareness must be created among local people regarding CBR and its purpose, along with preparation of landscape waterscape maps, and toposheets.
2. Practical ecological knowledge: This should be collected through adequate surveys and documented. All knowledge relating to biodiversity status and utilisation should be collected and; documented.
3. Claims: This will enlist and record all the claims of local people regarding properties used and processes relating to bioresources irrespective of whether such uses and properties have been proved or not.
4. Scientific knowledge: Al1 other scientific information provided by local people regarding biodiversity elements should be .documented. Ideally, there should be one CBR per village/society settlement in the preparation of which one or more educational institutions of that area may be involved. All members outside that particular community are then refused normal access to the details contained in the register; conditions are then set to allow others access to such data. Community registers can be advantageously used as documentary evidence of indigenous knowledge if there are legal disputes involving biopiracy.

Databases and Networks on IKS

Some progressive thinking traditional societies have already established databases on their IKS. They essentially control these databases for access and use of knowledge. The most notable traditional society in this regard is the Canadian Inuit of Nunavik and the Dene.

Traditional societies are increasingly using electronic networks to exchange knowledge and information. A few such efforts are described here. The Indigenous People’s Biodiversity

Network (IPBN) is a global network of organisations of indigenous people working in the area of biodiversity conservation, especially in protecting IKS relating to bioresources. IPBN has already formulated suitable policies, laws and programmes in the above area of conservation especially significant is its development of *sui generis* systems for protecting DCS on genetic resources. Working Groups have been established in the Americas, Asia and Africa, which have agreed to exchange ideas, share knowledge, and raise issues relating to protection of their DCS.

The other organisation worthy of mention is the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI), initiated by Prof. Anil Gupta of the Indian Institute of Management. SRISTI has already established communications with about 300 villages of India. SRISTI's main objectives are capacity-building at grassroots level in biodiversity conservation, protecting IPRs, adding more information to their IKS through further efforts and experiments, development of entrepreneurial enterprises among-traditional people using IKS and enrichment of their cultural and institutional base.

SRISTI also offers technical, developmental and legal/counseling help not only to the innovative efforts of traditional people, but also to their DCS relating to genetic resources. Village people are also trained in sustainable developmental activities. SRISTI has already-established a computer database on IKS.

Community Controlled Research

CCR (Community Controlled Research) fulfils the objectives and methodologies formulated by indigenous peoples themselves. For instance, the Kuna tribe of Panama and the Inuit tribe of Canada have not only established CCRs, but have decided to allow only such research in their territories. According to Posey, (1997), the Proyecto de Estudio para el Mahejo tie Areas Silvestres de Kuria Yala (AEK) of Panama has prepared an Information Manual for researchers of their area. External collaborative research is allowed, and even encouraged, provided such research is designed to provide the Kuna with information Useful to them and under their control. Similarly, an article 'Negotiating Research Relationship in the North' has been prepared which delineates the ethical principles of Inuit communities to be followed by researchers of that community. For more information on research principles for CRR suggested by this community, Posey, (1997).

Centre for Farmers' Rights

The term 'Farmers Right' was developed in the 1983 forum of the International Commission on Plant Genetic Resources of FAO chaired by Professor M.S. Swaminathan to denote 'the rights arising from the past, present and future contributions of farmers in conserving, improving and making available plant genetic resources, in particular those in the centres of origin/diversity (Swaminathan 1987). Subsequently a dialogue was organised in 1990 at Madras (now called Chennai) in the M.S.Swaminathan Research Foundation (MSSRF) in collaboration with the Keystone Centre of US, wherein it was agreed to create a fund for Farmers' Rights.

A draft legislation was also framed 'for converting the know-how relating to Farmers' Rights into do-how'. Now there is absolutely no difference of opinion about the need to recognise and reward the contributions of traditional farmers and indigenous tribals to the conservation as well as improvement of germplasms of crop plants. The concept of Farmers' Rights aims at benefit- sharing through a process of compensation for the use of traditional knowledge systems, in contrast to the system of internalisation of benefits, already referred to on page 189. The charter of Farmers' Rights includes the following rights (Shiva and Ramprasad 1993): (i) right to land; (ii) right to conserve, reproduce, and modify seed and plant material; (iii) right to feed, to ensure food security and to save the country; (iv) right to just agriculture prices and public support for sustainable agriculture; (v) right to information; (vi) right to participatory research; (vii) right to natural resources; and (viii) right to safety and health.

The Plant Variety Protection Acts introduced in advanced countries generally conform, to the provisions stipulated by the UPOV Act of 1991 version. Because of this Act, it has become necessary to classify the Farmers' Rights into two distinct categories (Swaminathan 1997):

1. Farmer cultivators: Farmers cultivating new varieties of crops by buying seeds should have unrestricted rights to keep seeds for raising crops in their own fields for successive generations. They should also be allowed to enter into a very limited sale/ exchange of seeds with their immediate neighbours.
2. Farmer conservers: Those indigenous people who have preserved land races and varieties raised by them through their own selection belong to this category. It is for this category of Farmers that protection should be given under 'Farmers' Rights' There was a strong recommendation, and rightly so, in the UPOV that a balance should be struck between homogeneity and heterogeneity in the genetic make-up of new cultivars' (Swaminathan l997).

As a sequel to this strong proposition, a Resource Centre for Farmers' Rights was organized in MSSRF Chennai, India. The government of India has planned the establishment of a National Community Gene Fund for rewarding farmers’ efforts in maintaining agrobiodiversity. This constitutes the first legal recognition and reward of Farmers' Rights, based on remuneration rights.

This Resource Centre is involved in the following four activities:

1. Farmers' Rights Information Service (FRIS). FRIS is a collection of several component databases such as intellectual property rights database (with four modules respectively Tribal contributions, Ethnobotanical features, Sacred groves, and rare Angiosperms) and multimedia database on the ecological farmers of India.
2. Community Gene Bank: this is meant for storing seeds of land races, traditional, cultivars and folk varieties.
3. Community Genetic Resources Herbarium: this Herbarium is meant to serve as a reference centre for the identification of rare and threatened flowering plant species, economically useful plants and traditional cultivars.
4. Lastly, creation of an Agrobiodiversity Conservation Corps to train young tribal and rural women and men in *in-situ* and *ex-situ* conservation techniques and seed technology.

Role of Women

It was pointed out earlier in this chapter that IKSs in several indigenous societies were held by women only or shared by both men and women. Women have traditionally played a key role in seed and plant selection and preservation, especially in PGRs. Women in some Indian and other Old World traditional societies, are responsible for the selection of viable and healthy seeds. Statistics show that women contribute to more than half the food grown every year in the developing countries (Damodaran 1997). It is also true that women and children are the first and worst victims of biodiversity degradation. If participation of the entire traditional society is needed in biodiversity development and conservation, 50% of the population should be women empowered for that purpose. It has been repeatedly demonstrated in the past that women's participation has been successful in solving pressing and acute environmental problems, e.g:

a. The role of tribal women in the Chiku dam issue in the Philippines;
b. The Chipko movement in the Himalayas;
c. The non raging Narmada Valley agitation spear headed by Medha Patkar;
d. The struggle of women for recognition as farmers in Burkino, Kenya, Nigeria and Zambia.

Efforts should be made immediately to see that women establish themselves managers of natural resources through education, awareness and action and society should ensure every assistance possible, including financial, to women in all these endeavours.

Problems and Prospects of Participatory management of Biodiversity

Reconciling economic growth with biodiversity Conservation has become a major and acute a problem in sustainable development in remote indigenous societies and traditional farming communities. While on the one hand these societies and the countries housing them lack adequate funds to venture into conservation -actions, there is the problem of not only protecting their DCS from bioprospecting piracies, but also rectifying the lack of equitable sharing of benefits accruing from such knowledge-sharing. As a result of these concerns, an increasing number of efforts are underway by the respective governments, NGOs, international organisations and the indigenous communities themselves to link biodiversity conservation protecting their IKS and equitable sharing benefits through internalisation of exist expected benefits. A number of projects have been launched towards this goal of participate management of biodiversity.

One of the major problems in participatory management efforts is the response of the local people/tribal society themselves, either because of the short duration of the projects executed thus far, or because of failure of the projects to elicit the required participation of locals. More efforts should focus on educating the traditional peer about the likely advantages of participation approaches in sharing benefits equitably and the same time in a sustainable manner. Second such participatory programmes have not real very many indigenous societies, especially in developing countries, in spite of efforts by organisations as GEF, which had already committed as of 1997 a sum of $300 million more than 50 developing countries. Third least some of the NGOs who are entrusted this job of familiarizing participatory approach to rural communities by national and international funding organisations have satisfactorily carried out the missions entry to them or have mismanaged them.

10 Natural Resources: Renewable and Non-Renewable

Energy expert Amory Lovins built a large, passively heated, super insulated, partially earth-sheltered home and office in Snowmass, Colorado, where winter temperatures can drop to -40°C (-40°F).This structure also houses the research center for the Rocky Mountain Institute, an office used by 40 people. This office-home gets 99% of its space and water heating and 95% of its daytime lighting from the sun arid uses one-tenth the usual amount of electricity for a structure of its size. With today's super insulating windows a house can have large numbers of windows without much heat loss in cold weather or heat gain in hot weather? Thinner insulation material now being developed will allow roofs and walls to be insulated far better than in today's best super insulated houses.

A small but growing number of people in developed and developing countries are getting their electricity from *solar cells* that convert sunlight directly into electricity. They can be attached like shingles to a roof, used as a roof material; or applied to window grass as a coating. Solar-cell prices are high but are falling. Many scientists and executives of oil and automobile companies believe we are in the beginning stages of a *solar-hydrogen revolution* to be phased in during this century as the Age of Oil begins winding down. Electricity produced by large banks of solar cells or farms of wind turbines could be passed through water to make hydrogen gas (H_2). This clean-burning fuel could be used to fuel vehicles, industries, and buildings. Am other solution is to burn hydrogen in energy-efficient *fuel cells* that produce electricity to run cars and appliances, heat water and heat and cool buildings

Burning-hydrogen made by decomposing water produces water vapor and no carbon dioxide (CO_2). Thus shifting to hydrogen as our primary energy resource during this century would eliminate most of the world's air pollution. This would also greatly slow global warming as long as the hydrogen is produced from water and not fossil fuels or other carbon-containing compounds. If the United States wants to save a lot of oil and money and increase national security, there are two simple ways to do it: Stop driving Petropigs and stop living in energy sieves.

The importance of improving energy efficiency

What Is Energy Efficiency? Doing More with Less Energy efficiency is the percentage of total energy input into an energy conversion device or system that does useful work and is not converted to low quality, essentially useless heat. Improving the energy efficiency of a car motor, home heating system, or other energy conversion device involves using less energy to do more useful work.

How Much Energy Do We Waste? You may be surprised to learn that 84% of all commercial energy used in the United States is wasted (Figure 10.1). About 41% of this energy is wasted automatically because of the degradation of energy quality imposed by the second law of thermodynamics. However, about 43% is wasted unnecessarily. This waste is caused mostly by using fuel-wasting motor vehicles, furnaces, and other devices an4 living and working in leaky, poorly insulated, poorly designed buildings.

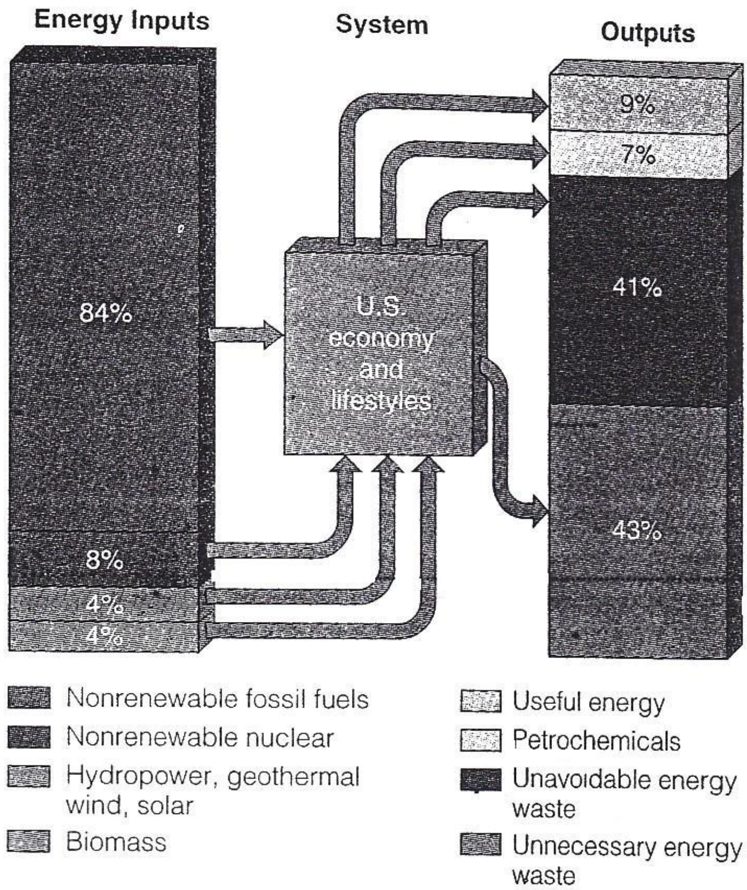


Figure10.1: Flow of commercial energy through the U.S. economy. Note that only 16%.of.aJJ.commercial energy used in the. United States ends up performing useful tasks or being converted to petrochemicals; the rest is either automatically or unavoidably wasted because of the second iaw of thermodynamics (41 %) or wasted unnecessarily (43%)

According to the U.S. Department of Energy (DOE), the United States unnecessarily wastes as much energy as two-thirds of the world's population consumes. Improvements in energy efficiency since the OPEC oil embargo in 1973 have cut U.S. energy bills by $275 billion a year. But unnecessary energy waste still costs the United States about $300 billion per year—

an average of $570,000 per minute. Reducing energy waste has a number of economic and environmental advantages (Figure 10.2).

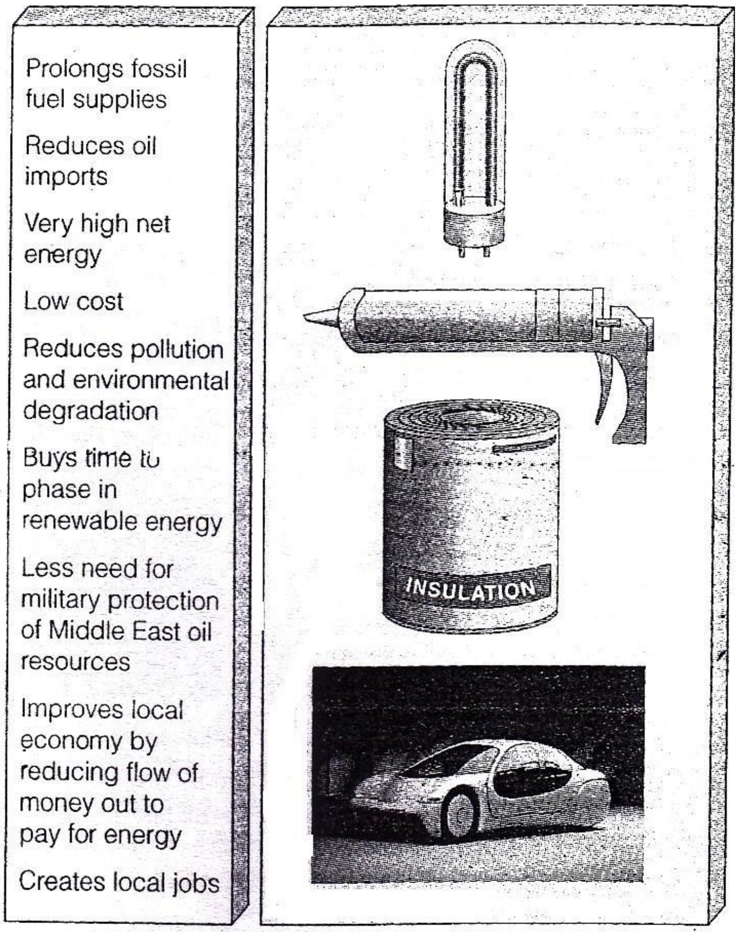


Figure 10.2: Solutions: advantages of reducing energy waste. Global improvements in energy efficiency could save the world about $1 trillion per year—an average of $114 million per hour

The United States (and most other developed countries) has come a long way in improving energy efficiency and saving money. But there is an exciting opportunity to do much better because the country still unnecessarily wastes almost half the energy it uses. Sharply reducing this energy waste will benefit the environment, people, and the economy.

What Are the Energy Efficiencies of Common Devices? The energy conversion devices we use vary in their energy efficiencies (Figure 10.3). We can save energy and money by buying more energy-efficient cars, lighting, heating systems, water heaters, air conditioners, and appliances. Some energy-efficient models may cost more initially, but in the long run they usually save money by having a lower life cycle cost: initial cost plus lifetime operating costs.

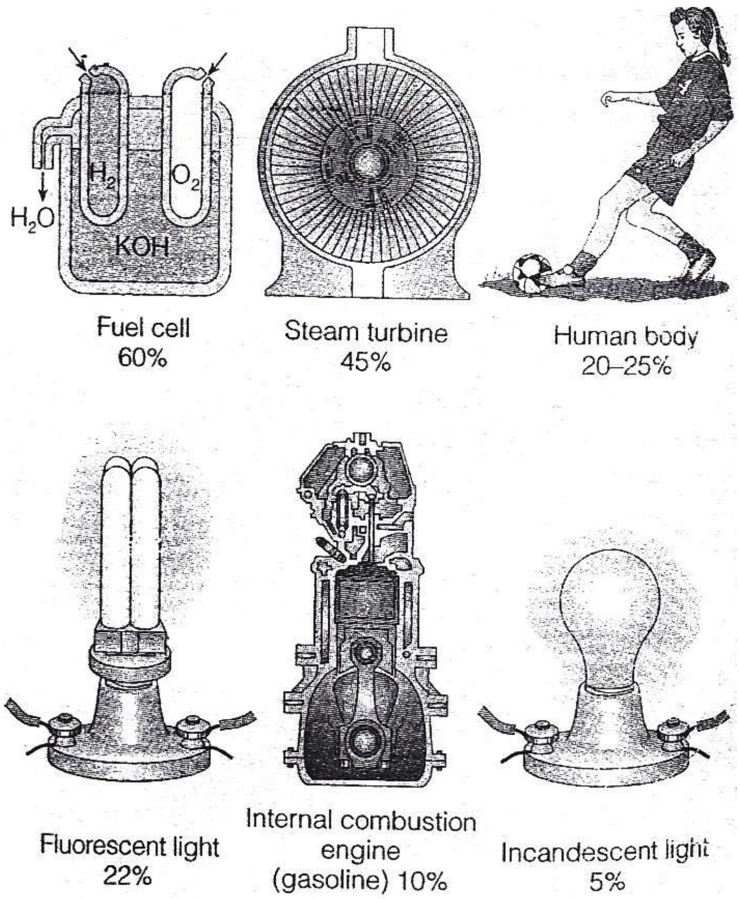


Figure 10.3: Energy efficiency of some common energy conversion devices

Here are three of the world's most energy-inefficient devices in widespread use today. *First* is the *incandescent light bulb,* which wastes 95% of its energy input of electricity. In other words, it is a *heat bulb. Second* is a motor vehicle with an *internal combustion engine,* which wastes 86-90% of the energy in its fuel. *Third* is a *nuclear power plant* producing electricity for space heating or water heating? Such a plant wastes about 86% of the energy in its nuclear fuel and probably 92% when the energy needed to deal with its radioactive wastes and to retire the plant is included. Energy experts call for us to replace these devices or greatly improve their energy efficiency over the next few decades.

Coal-burning power plants also are big energy wasters. About 34% of the energy in coal burned in a typical electric power plant is used to produce electricity. However, the remaining 66% ends up as waste heat that flows into the environment. As a result, U.S. coal-burning power plants throw away as much heat as all the energy used by Japan.

What Is Net Energy Efficiency? Recall that the only energy that really counts is *net energy*. The *net energy efficiency* of the entire energy delivery process for a space heater, water heater, or car is determined by the efficiency of each step in the energy conversion process

Figure 10.4 shows the net energy efficiency for heating two well-insulated homes. One is heated with electricity produced at a nuclear power plant, transported by wire to the home, and converted to heat (electric resistance heating). Tire other is heated passively: direct solar energy enters through high-efficiency windows facing the sun and strikes heat-absorbing materials that store the heat for slow release.

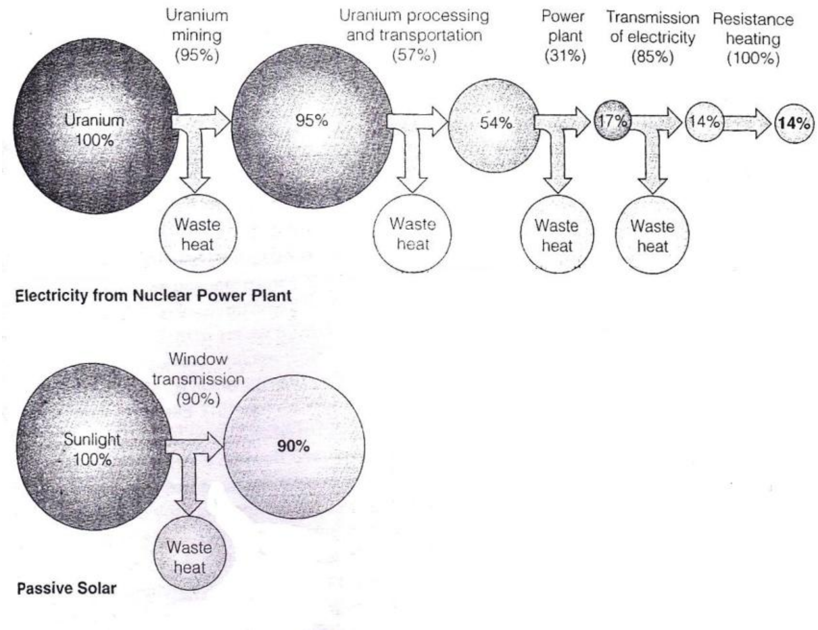


Figure 10.4: Comparison of net energy efficiency for two types of space heating

The cumulative net efficiency is obtained by multiplying the percentage shown inside the circle for each step by the energy efficiency for that step (shown in parentheses). Because of the second law of thermodynamics, in most cases the greater the number of steps in an energy conversion process, the lower its net energy efficiency. About 86% of the energy used to provide space heating by electricity produced at a nuclear power plant is wasted. If the additional energy needed to deal with nuclear wastes and to retire highly radioactive nuclear plants after their useful life is included, then the net energy yield for a nuclear plant is only about 8% (or 92% waste). By contrast, with passive solar heating, only about 10% of incoming solar energy is wasted.

This analysis shows that converting the high-quality energy in nuclear fuel to high-quality heat at several thousand degrees in the power plant, converting this heat to high-quality electricity, transmitting the electricity to users, and using the electricity to provide low-qualify heat for warming a house to only, about 20°C (68°F) is very wasteful of high-quality energy. Burning coal or any fossil fuel at a power plant to supply electricity and transmitting it long distances to heat water or space is also inefficient. This example illustrates two general principles for saving energy. *First,* keep the number of steps in an energy conversion process as low as possible. Each time we convert energy from one form to another or transmit it, some useful energy is lost. *Second,* strive to have the highest possible energy efficiency for each step in an energy conversion process.

Ways to Improve Energy Efficiency

How Can We Use Waste Heat? Could we save energy by recycling energy? No. The second law of thermodynamics tells us that we cannot recycle energy. But we can slow tire rate at which waste heat-flows into the environment when high-quality energy is degraded. For a house, the best way to do this is to insulate it thoroughly eliminate air leaks and equip it with an air-to-air heat exchanger to prevent buildup of indoor air pollutants.

In office buildings and stores, waste heat from lights, computers, and other machines can be collected and distributed to reduce heating bills during cold weather. During hot weather, the collected heat can be vented outdoors to reduce cooling bills or to drive a type of air conditioner called an *absorption chiller.*

How Can We Save Energy and Money in Industry? One way some industries save energy and money is to use cogeneration, or combined heat-and power (CHP) systems. In such a system two use forms of energy (such as steam and electricity) are produced from the same fuel source. These systems h; an efficiency of up to 80% (compared to about 30-40. for coal fired boilers and nuclear power plants) and emit two-thirds less $C0_2$ per unit of energy product than conventional coal-fired boilers.

Cogeneration has been widely used in western Europe for years. Its use in the United States (where it now produces only 9% of the country's electricity) a China is growing. In Germany, small cogeneration units that run on natural gas or liquefied petroleum gas (LPG) supply restaurants, apartment buildings, and houses with all their energy. In 6-8 years, they pay §r themselves in saved fuel and electricity.

Another way to save energy and money is to replace energy-wasting electric motors. Running electric motors (mostly in industry) consumes about one-fourth of the electricity produced in the United States. Most of these motors are inefficient because they run only at full speed with their output throttled to match the task. Each year a heavily used electric motor consumes 10 times its purchase cost in electricity equivalent to using $200,000 worth of gasoline each year to fuel a $20,000 car. The costs of replacing such motors with new adjustable-speed drive motors would be paid back in about 1 year and save an amount of energy equal to that generated by 150 large (1,000-megawatt) power plants. A *third way* to save energy is to switch from low-efficiency incandescent lighting to higher-efficiency fluorescent lighting.

Technology is the answer (But what was the question?)

Physicist and energy consultant Amory B. Lovins is one of the world's most respected experts on energy strategy. In 1989, he received the Delphi Prize for environmental work; in 1990, the Wall Street Journal named him one of the 39 people most likely to change the course of business in the 1990s. He is research director at Koch/ Mountain Institute, a nonprofit resource policy center that lie and Hunter Lovins founded in Snowmass, Colorado, in 1982. He has served as a consultant to more than 200 utilities, private industries, and international organizations, and to many national, state, and local governments. He is active in energy affairs in -more than' 55 countries and has published several hundred papers and a dozen hooks on energy strategies and policies.

It is fashionable to suppose that we're running out of energy and ask how we can get more of it. However, the more important questions are the following: How much energy do we need? What are the cheapest and least environmentally harmful ways to meet these needs? How much energy it takes to make steel, run a car, or keep ourselves comfortable in our houses depends on how cleverly we use energy For example, it is now . cheaper to double the efficiency of most industrial electric motor drive systems than to fuel existing power plants to make electricity. Just this one saving can more than replace the entire 0.S. nuclear power program. We know how to make lights five times as efficient as those currently in use and household appliances that give us the same work as now but use one-fifth as much energy (saving money in the process).

Within a decade automakers could have cars getting 64-128 kpl (150-300 mpg) on the road if consumers demanded such cars. We know today how to make new buildings (and many old ones) so heat-tight (but still well ventilated) that they need essentially no outside energy to maintain comfort year-round, even in severe climates. In fact, I live and work in one. These energy-saving measures are all cheaper than going out and getting more energy However, the old view of the energy problem included a worse mistake than forgetting to ask how much energy we needed: It sought more energy, in any form, from any source, at any price, as if all kinds of energy were alike.

Just as there are different kinds of food, so there are many different forms of energy whose different prices and qualities suit them to different uses. After all, there is no demand for energy as such nobody wants raw kilowatt-hours or barrels of sticky black goo. People instead want energy services comfort light, mobility, hot showers, cold beverages, and the ability to cook food and make cement. In developing energy resources we should start by asking, "What tasks do we want energy for, and what amount, type, and source of energy will do each task most cheaply?"

The real question is, "What is the cheapest way to do low-temperature heating and cooling?" The answer is weather-stripping, insulation, heat exchangers, greenhouses, super windows (which have as much insulating value as the outside wall of a typical house) root over-hangs, trees, and so on. These measures generally cast fee equivalent of buying electricity at about 0.5-2 per kilo-watt-hour, the lowest-cost way by far to supply energy.

If we need more electricity, we should get it from the cheapest sources first. In approximate order of increase price, these include

- Converting to efficient lighting equipment. This would save the United states electricity equal to the output of 120 large power plants, plus S30 billion a year in fuel and maintenance costs.
- Using more efficient electric motors to save up to half the energy used by motor systems. This would save electricity equal to the output of another 150 large power plants and repay the cost in about a year.
- Displacing the electricity now used for water heating and for space heating and cooling with good architecture, weatherization, insulation, and mostly passive solar techniques.
- Improving the energy efficiency of appliances, smelters, and the like.

Just these four measures can quadruple U.S. electrical efficiency, making it possible to run today's economy" with no changes in lifestyles and using no power plants, whether old or new or fueled with oil, gas, coal, uranium, or solar energy. We would need only the present hydroelectric capacity, readily available-small scale hydroelectric projects, and a modest amount of wind power.

To emphasize the importance of starting with energy end uses rather than energy sources, consider a story from France. In the mid-1970s, energy conservation planners in the French government found that their biggest; need for energy was to heat buildings and that even with, good heat pumps, electricity would be the costliest way to do this. So they had a fight with their government owned and run utility company; they won, and electric heating was supposed to be discouraged or even phased but because it was so wasteful of money and fuel.

Meanwhile, down the street, the energy supply planners (who were far more numerous and influential in the French government) said, "Look at all that nasty imported oil coming into our country. We must replace that oil with some other source of energy. Voila Nuclear reactors can give us energy, so we'll build them all over the country." However, they paid little attention to that would, use that extra energy and no attention to relative prices.

Thus, these two groups of the French energy establishment went on with their respective solutions to two different, indeed contradictory, French energy problems: more energy of any kind versus the right kind to do each task in the most inexpensive way. It was only in 1979 that these conflicting perceptions collided. The supply side planners suddenly realized that the only thing they would be able to sell all that nuclear electricity for would be electric heating, which they had just agreed not to do. Every industrial country is in this embarrassing position. Supply-oriented planners flunk the problem boils down to whether to build coal or nuclear power stations (or both). Energy use planners realize that no kind of new power station can be an economic way to meet the needs tor using electricity to provide low and high temperature heat and for the vehicular liquid fuels that is 92% of our energy problem. So if we want to provide energy services at the lowest cost, we need to begin by determining what we need the energy for.

How Can We Save Energy in Transportation?

According to most energy analysts, the best way to save energy (especially oil) and money in transportation is to increase the fuel efficiency of motor vehicles. Some good environmental news is that between 1973 and 1985, the average fuel efficiency rose sharply for new cars sold in the United States and to a lesser degree for pickup trucks, minivans, and sport utility vehicles (SUVs) (Figure 3.5). This occurred because, of the government-mandated Corporate Average Fuel Economy (CAFE) standards. Some bad environmental news is that between 1985 and 2003, the average fuel efficiency for new motor vehicles sold in the United States leveled off or declined slightly (Figure 10.5).

One reason for this is the increased popularity of-energy-inefficient sport utility vehicles (SUVs), minivans, light trucks, and large autos that also produce about 20% of U.S. emissions of $C0_2$. Another reason is failure of elected officials to raise CAFE standards since 1985 because of opposition from automakers. A 2001 study by the American Council for an Energy-Efficient Economy (ACEEE) analyzed the effects of increasing the fuel economy of new vehicles in the United States by just 5% a year for 10 years. Doing this would save 10-20 times more oil than the projected supply from the Arctic National Wildlife Refuge and more than three times the oil in the nation's current proven oil reserves.

Suppose that in 1991 the first Bush administration and Congress had established a policy of requiring that the average car in the United States get 14 kilometers per liter (kpl) [32 miles per gallon (mpg)] by 2001. According to energy analysts, doing this would have saved enough oil to eliminate all current oil imports to the United States from the Persian Gulf. A similar action by the second Bush administration and Congress could significantly reduce U.S. dependence on imported oil within 10 years.

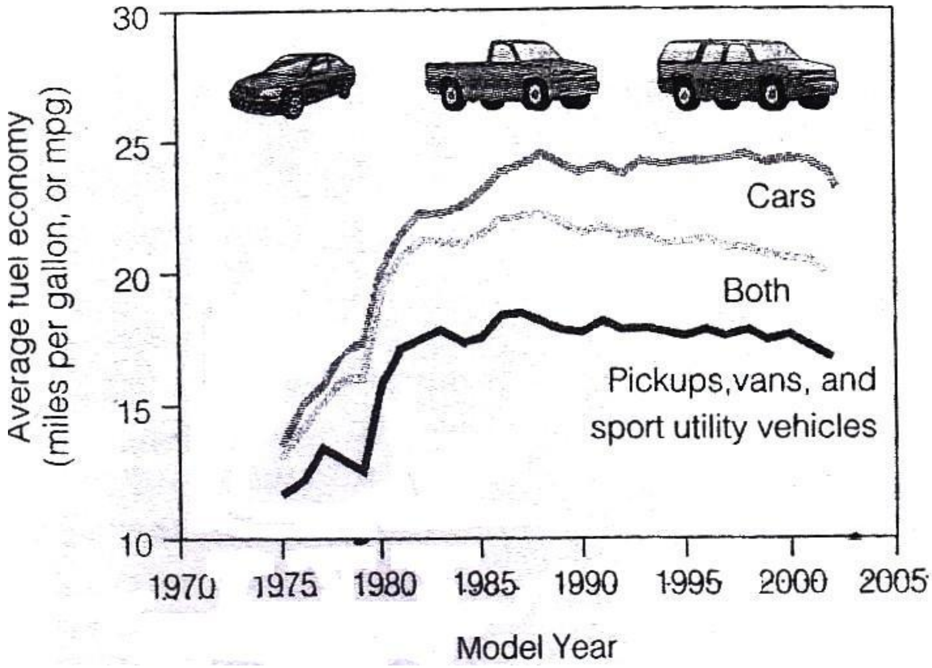


Figure 10.5: Average fuel economy of new vehicles sold in the United States, 1975-2003. (Datafrom U.S. Environmental Protection Agency and National Highway Traffic Safety Administration)

Here are two pieces of bad environmental news. First only 33 of the 934 cars, trucks, and vans on the market in the United States in 2003 got more than 13 kpl (30 mpg). Second, such models account for less than 1% of all car sales. One reason for this is that the inflation-adjusted price of gasoline today in the United States is low (Figurz 10.6 and Connections, right). A second reason is that two-thirds of U.S. consumers prefer SUVs, pickup trucks, minivans, and other large, inefficient vehicles. In Europe, where gasoline costs $0.80-1.30 per liter ($3-5 per gallon), .subcompact cars are in much greater use especially for urban trips. For example, Volkswagen has a four seater subcompact car that gets 33 kpl (78 mpg) and has begun producing a smaller model that gets 100 kpl (235 mpg).

Are Hybrid-Electric Vehicles the Answer?

There is rapidly growing interest in developing superefficient cars that could eventually get 34-128 kpl (80-300 mpg). One type of energy-efficient car uses a small hybrid-electric internal combustion engine. It runs on gasoline, diesel fuel, or natural gas and a small battery (recharged by the internal combustion engine) to provide the energy needed for acceleration and hill climbing .

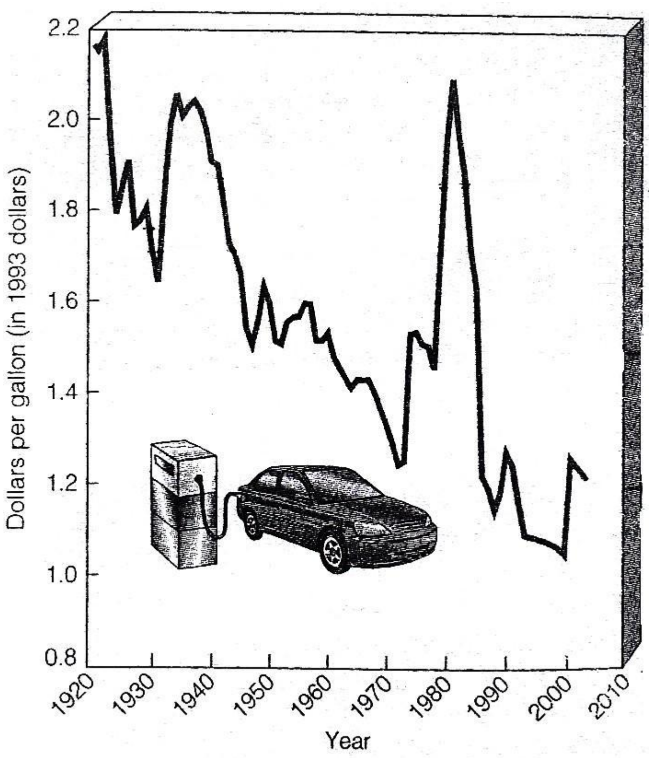


Figure 10.6: **Real price of gasoline (in 1993 dollars) in the United States, 1920-2002. The 225 million motor vehicles in the United States use about 40% of the world's gasoline. Gasoline is one of the cheapest items American consumers buy and is less expensive than bottled water. (U.S. Department of Energy**

Are Fuel-Cell Cars the Answer? Another type of superefficient car is an electric vehicle that uses a fuel cell that burns hydrogen (H2) fuel to produce the electricity. In the cell, the hydrogen fuel (H_2) combines with oxygen (O_2) in the air to produce electrical energy to power the car and emits water vapor (H_20) into the atmosphere. Most major automobile companies have developed prototype fuel-cell cars and plan to market a variety of such vehicles by 2010.

The Real Cost of Gasoline in the United States

Economists and environmentalists point out that gasoline costs U.S. consumers much more than it appears. This is because most of the real cost of gasoline is not paid directly-at the pump. According to a 1998 study by the International Center for Technology Assessment, the hidden costs of gasoline to U.S. consumers are about $130-3.70 per liter ($5-14 per gallon), depending on how the costs are estimated. These hidden costs include government subsidies and tax breaks for oil companies and road builders, pollution control and cleanup, military protection of oil supplies in the Middle East, and environmental, health, and social costs. Such costs include increased medical bills and insurance premiums, time wasted in traffic jams, noise pollution, increased mortality from air and water pollution, urban sprawl, and harmful effects on wildlife species and habitats.

Economists point out that if these harmful costs were included as taxes in the market price of gasoline, we would have-much more energy-efficient and less polluting cars. However, gasoline and car companies benefit financially by being able to pass these hidden costs on to consumers and future generations. This is basically an education and political problem. Most consumers are unaware that they are paying these harmful costs and do not connect them with gasoline use. Also, politicians running on a platform of raising gasoline prices 3- to 11-fold in the United States would be committing political suicide.

How Can Electric Bicycles and Scooters Reduce Energy Use and Waste? For urban trips, more people may begin using electric bicycles powered by a small electric motor. These bicycles, now being sold by several companies, cost $500-1,100 and travel at up to 32 kilometers per hour (kph) [20 miles per hour (mph)]. They go about 48 kilometers (30 miles) without pedal-ing on a full electric charge and produce no pollution during operation (and only a small amount for the electricity used in recharging them).

In 2003, an electric bicycle powered by a small fuel cell became available for about $1,500-2000. A small metal container (similar to a propane gas container) that can be easily disconnected and refilled within seconds supplies the hydrogen. Another alternative is an electric scooter. One model, the Nova Cruz Voloci, has a range of about 81 kilometers (50 miles), can travel at a top speed of 48 kph (30 mph), and costs about $2,500

How Can We Design Buildings to Save Energy?

Atlanta's 13-story Georgia Power Company building uses 60% less energy than conventional office buildings of the same size. The largest surface of the building faces south to capture solar energy. Each floor extends out over the one below it. This blocks out the higher summer sun to reduce air conditioning costs but allows warming by the lower winter sun. Energy-efficient lights focus on desks rather than illuminating entire rooms. If phased in over two to three decades, the Georgia Power model and other existing cost-effective commercial building technologies could reduce energy use by 75% in U.S. buildings and cut $C0_2$ emissions from buildings in half. This would save more than $130 billion per year in energy bills an average of $15 million an hour.

Another energy-efficient design is a super insulated house (Figure 10.7). Such houses typically cost 5% more to build than conventional houses of the same size. But this extra cost is paid back by energy savings within about 5 years and can save a homeowner $50,000-100,000 over a 40-year period.

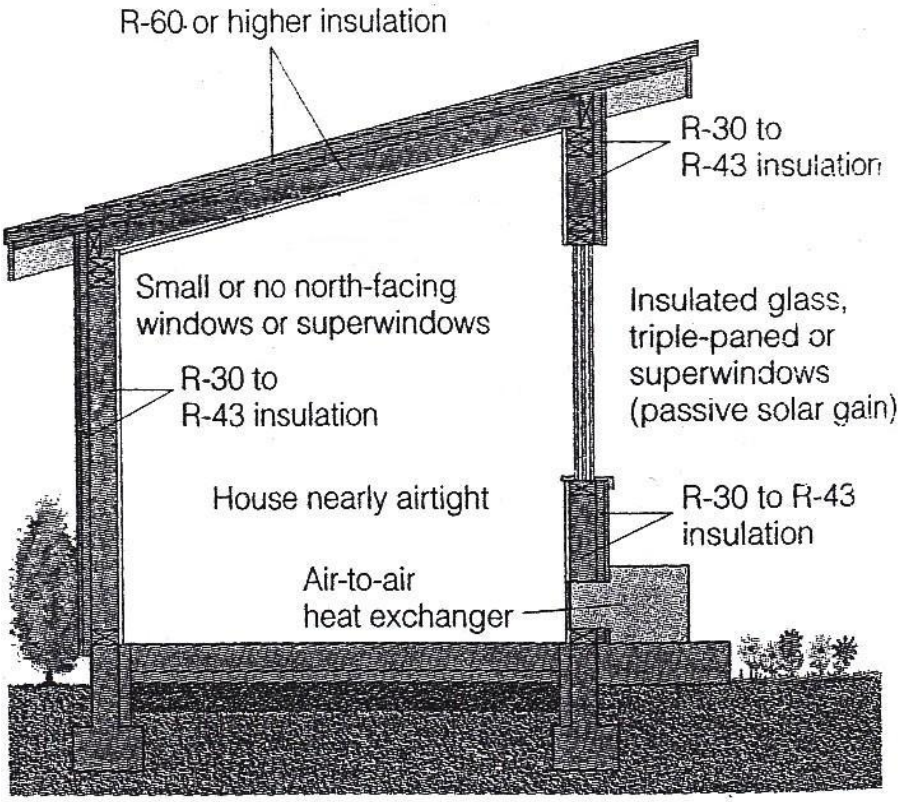


Figure 10.7: Solutions: major features of a *superinsulateci house.* Such a house is so heavily insulated and so airtight that it can be warmed by heat from direct sunlight, appliances, and human bodies, with little or no need for a backup heating system. An air-to-air heat exchanger prevents buildup of indoor air pollution

Since the mid-1980s there has been growing interest in building super insulated houses called *straw-bale houses.* Their walls consist of compacted bales of certain types of straw, which are widely available at a low cost. Then the walls are covered with plaster or adobe. By 2002, more than 1,200 such homes had been built or were under construction in the United States. Making the walls from straw, an annually renewable agricultural residue often burned as a waste product, reduces the need for wood and thus slows deforestation. The main problem is getting banks and other moneylenders to recognize the potential of this and other unconventional types of housing and provide homeowners with construction loans. Eco-roofs covered with plants have been used in Germany and in other parts of Europe for about 25 years. These plant-covered roof gardens provide good insulation, absorb storm water, and outlast conventional roofs.

How Can We Save Energy in Buildings? An important way to save, energy is to use the most energy efficient ways to heat houses (Figure 10.8). The most energy-efficient ways to heat space, in order, are a super insulated house, passive solar heating, heat pumps in warm climates (but not in cold climates because at low temperatures they automatically switch to costly electric resistance heating), and high-efficiency (85-98%) natural gas furnaces. The most wasteful and expensive way is to use electric resistance hearing with the electricity, produced by a coal fired or nuclear power plant.

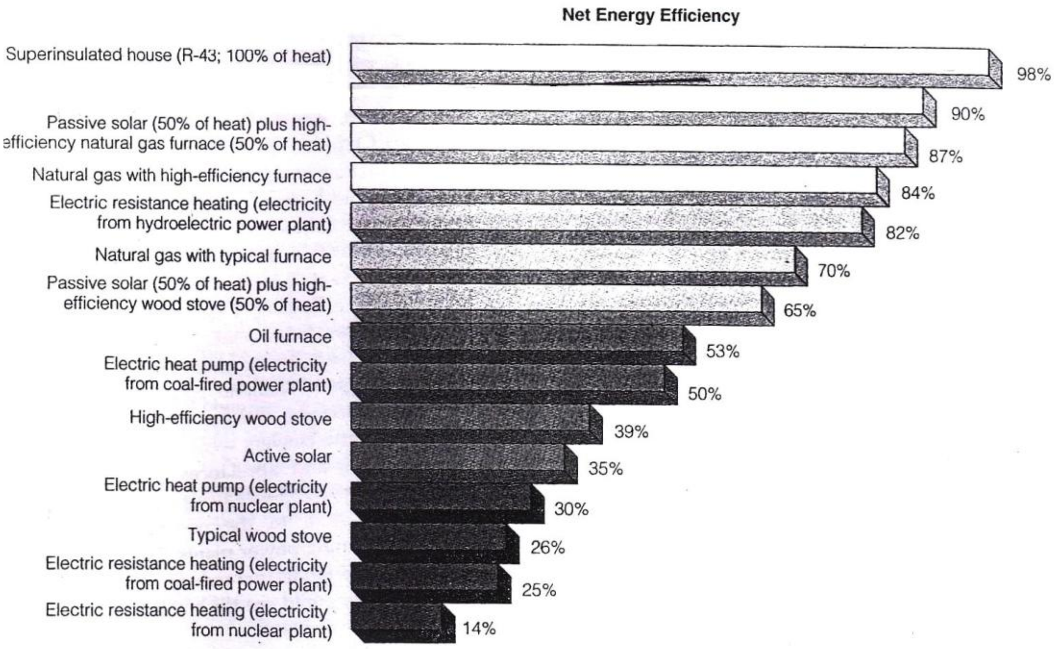


Figure 10.8: Solutions: Ways to heat an enclosed space such as a house, ranked by net energy effieciency

The energy efficiency of existing houses and buildings can be improved significantly by adding insulation, plugging leaks, and installing energy-saving windows and lighting. About one-third of heated air in U.S. homes and buildings escapes through closed windows and holes and cracks equal to the energy in all the oil flowing through the Alaska pipeline every year. During hot weather these windows and cracks also let heat in, increasing the use of air conditioning. Between 1976 and 2002, the U.S. Department of Energy's Weatherization Assistance Program, which aids low-income Americans in making their homes more energy efficient, saved more than $1 billion in energy costs.

Replacing all windows in the United States with low-E (low-emissivity) windows would cut expensive losses from houses by two-thirds and reduce $C0_2$ emissions. Widely available super insulating windows insulate as well as 8-12 sheets of glass. Although they cost 10-15% more than double-glazed windows, this cost is paid back rapidly by the energy they save. Even better windows will reach the market soon.

Simply wrapping a water heater in a $20 insulating jacket can save $45 a year and reduce $C0_2$ emissions. Leaky heating and cooling ducts in attics and unheated basements allow 20-30%

of a home's heating and cooling energy to escape and draw unwanted moisture and heat into the home. Careful sealing can reduce this loss. Some designs for new homes keep the ducts inside the home's thermal envelope so that escaping hot or cool air leaks into the living space.

An energy-efficient way to heat hot water for washing and bathing is to use tank less instant water heaters (about the size of a small suitcase) fired by natural gas or LPG. These devices, widely used in many parts of Europe, heat water instantly as it flows through a small burner chamber, provide hot water only when it is needed, and use about 20% less energy than traditional water heaters. A well-insulated, conventional natural gas or LPG water heater is fairly efficient. But all conventional natural gas and electric resistance heaters waste energy by keeping a large tank of water hot all day and night and can run out after a long shower or two. Using electricity produced by any type of power plant is the most inefficient and expensive way to heat water for washing and bathing. A $425 electric water heater can cost $5,900 in energy over its 20-year life compared to about $4,000 for a comparable natural gas-water heater over the same period.

Cutting off lights, computers, TVs, and other appliances when they are not needed can make, a big difference ill energy rise and bills. At 9 P.M. one weekday evening, major TV stations in Bangkok, Thailand, cooperated with the government in showing a dial that gave the city's current use of electricity. Viewers were asked to turn off unnecessary lights and appliances. They then watched the dial register a 735-megawatt drop in electricity use—a drop equal to the output of two medium-sized coal-burning power plants. This visual experience showed individuals that reducing their unnecessary electricity use could cut their bills and collectively close down power plants.

Setting higher energy-efficiency standards for new buildings is another way to save energy. Building cones could require that all new houses use 60-80% less energy than conventional houses of the same size, as has been done in Davis, California. Because of tough energy-efficiency standards, the average Swedish home consumes-about one-third as much energy as the aver-age American home of the same size. Another way to save energy is to buy the most energy efficient appliances and lights. Since 1978, the Department of Energy (DOE) has set federal energy-efficiency standards for more than 20 appliances used in the United States. A 2001 study by the National Academy of Sciences found that between 1978 and 2000, the $7 billion spent by the DOE on this program saved consumers more than $30 billion in energy costs and provided environmental benefits valued conservatively at $60-80 billion. The 2001 study also projected that the program will save U.S. consumers another $46 billion in energy costs between 2000 and 2020. Programs like these exist in 43 other countries.

Energy-efficient lighting could save U.S. businesses and homes about $30 billion per year in electricity bills. Replacing a standard incandescent bulb with an energy-efficient compact fluorescent bulb (Figure 3.9) saves about $48-70 per bulb over its 10-year life. Thus replacing 25 incandescent bulbs (in a house or building) with energy-efficient fluorescent bulbs saves 1,250-1,750. Students in Brown University's environmental studies program showed that the school could save more than $40,000 per year just by replacing the incandescent light bulbs in exit signs with compact fluorescent bulbs.

In 2001, researchers at the Lawrence Berkeley National Laboratory developed a very efficient high-intensity fluorescent table lamp. It uses two independently controllable and fully dimmable compact fluorescent bulbs, one- directed downward and the other upward. The lamp can eliminate the need for overhead room lighting and also provide down lighting for reading and other tasks. It can also help decrease use of highly inefficient halogen bulbs, which can also start fires and increase air conditioning needs because of the intense heat they produce. In 2002, scientists at Sandia National Laboratories developed a new type of incandescent light bulb that raises the efficiency of such bulbs from 5% to about 60%.

If all households in the United States used the most efficient frost-free refrigerator now available, 18 large (1,000-megawatt) power plants could close. Microwave ovens can cut electricity use for cooking by 25-50% (but not if used for defrosting food). Clothes dryers with moisture sensors cut energy use by 15%, and front-loading washers use 50% less energy than top loading models but cost about the same. The spinX dryer which debuted in 2002 uses centrifugal force and minimal electricity to dry clothes. It can dry clothes in 2 minutes instead of 30 minutes in a conventional dryer.

Connections: How Can Using the Internet Save Energy and Paper and Reduce Global Warming? According to a 2000 report by researchers at the Center for Energy and Climate Solutions, increased use of the Internet for business and shopping transactions reduces energy use and decreases emissions of $C0_2$ and other air pollutants. For example, using the Internet for business transactions allows more employees to work at home and can reduce the need for retail, manufacturing, warehouse, and commercial office space. **Figure 10.9**

Some online companies keep no merchandise in warehouses and have it shipped to customers directly from manufacturers. For example, Amazon.com uses 1/16 as much energy per unit of floor space to/sell a book as a regular store. Internet use can also-reduce the energy, paper, and materials used to produce package, and market consumer items such as computer software and music CDs by downloading them.

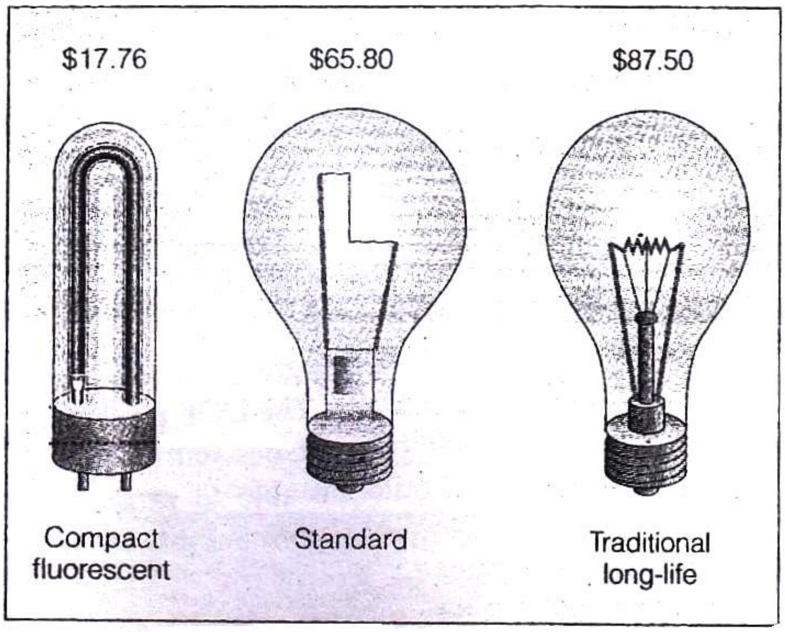


Figure 10.9: Solutions: Solutions: cost of electricity for comparable light bulbs used for 10,000 hours. Because conventional incandescent bulbs are only 5% efficient and last only 1,500 hours, they waste enormous amounts of energy and money and add to the heat load of houses during hot weather. Socket-type fluorescent lights use one-fourth as much electricity as conventional bulbs. Although these bulbs cost $6-15 per bulb, they last up to 100,000 hours (60-70 times longer than conventional incandescent bulbs and 25 times longer than halogen bulbs), saving a lot of money (compared with less efficient incandescent and halogen bulbs) over their long life. Between 1998 and 2001, global sales of compact fluorescent bulbs rose from 45 million to 606 million per year—with 80% of them made in China. (Data from Electric Power Research Institute)

Paper production (a highly energy- and resource-intensive industry) is expected to decrease as consumers use the Internet to download software and view magazines, newspapers, research articles, telephone directories, encyclopedias, and books. Paper use can also decrease as consumers and businesses send more e-mail and less conventional mail and more sellers replace paper catalogs with easily updated online catalogs. Although this book is printed on paper, I used no paper in preparing it for the publisher. Instead, the manuscript was sent to the publisher electronically as attachments to e-mail messages. Copyediting of the manuscript was also done via e-mail attachments. We can also envision a day not too far away when we can read and interact with most textbooks on websites maintained by book .publishers or individual authors. **Figure 10.10**

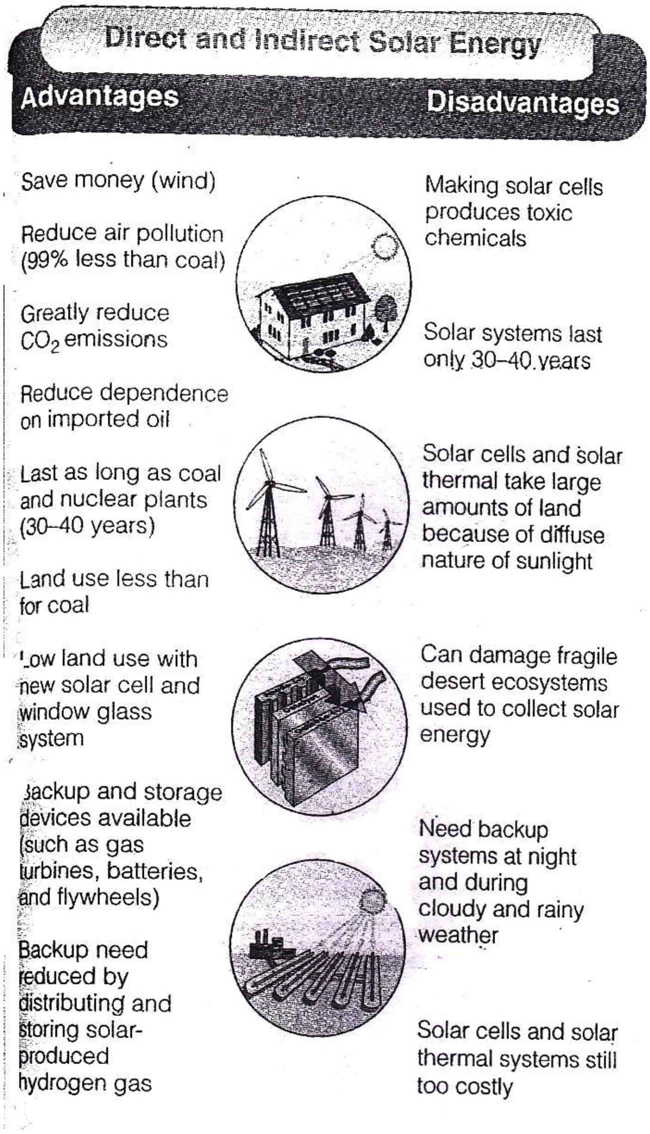


Figure 10.10: Trade offs: major advantages and disadvantages of using direct and indirect solar energy systems to produce heat and electricity. Specific advantages and disadvantages of different direct and indirect solar and other renewable energy systems are discussed in this chapter

Why Are We Not Doing More to Reduce Energy Waste? With such an impressive array of benefits why is there so little emphasis on improving energy efficiency by governments, businesses, and consumers? There are three major reasons. First there is a glut of low-cost oil and gasoline. As long as energy is cheap, people are more likely to waste it and nut make investments in improving energy efficiency.

Second, there is a lack of sufficient government tax breaks and other economic incentives for consumers and businesses to invest in improving energy efficiency. Finally, there is a lack of information about the availability of energy saving devices and the amount of money such items can save consumers as revealed by life cycle cost analysis.

Using solar energy to provide heat and electricity

What Are the Major Advantages and Disadvantages of Solar Energy? One of the four keys to sustainability based on learning from nature is to rely mostly on renewable solar energy lists some of the advantages and disadvantages of making a shift to greatly increased use of dirt solar energy and indirect forms of solar energy such wind. Like fossil fuels and nuclear power each renewable energy alternative has a mix of advantages and disadvantages, as discussed in the remainder of this chapter. Here are four pieces of *good news* about the increased use of renewable energy. First, in 2001 the European Union (EU) adopted nonbinding agreements for its member countries to get 12% of their total energy and 22% of their electricity from renewable energy by 2010.

Second, California gets about 12% of its electricity i renewable resources. *Third,* a 2001 joint study by the American Council for an Energy-Efficient Economy, the Tellus Institute, and the Union of Concerned scientists showed how renewable energy could provide 20% of U.S. energy by 2020. *Finally,* according to Royal Dutch Shell International Petroleum, renewable energy could account for 50% of the world's energy production by 2050. The bad news is that solar and wind power currently provide only about 1% of the world's commercial energy—mostly because they have received and continue to receive much lower government tax breaks, subsidies, and research and development funding than fossil fuels and nuclear power. This creates an uneven economic playing field.

How Can We Use **Solar Energy to Heat Houses and Water?** Buildings and water can be heated by solar energy using two methods: passive and active. A passive solar heating system absorbs and stores heat from the sun directly within a structure Energy-efficient windows and attached greenhouses face the sun to collect solar energy by direct gain. Walls and floors of concrete, adobe, brick, stone, salt-treated timber, and water in metal or plastic containers store much of the collected solar energy as heat and release it slowly throughout the day and night. A small backup, heating system such as a vented natural gas or propane heater may be used but is not necessary in many climates. **Figure 10.11**

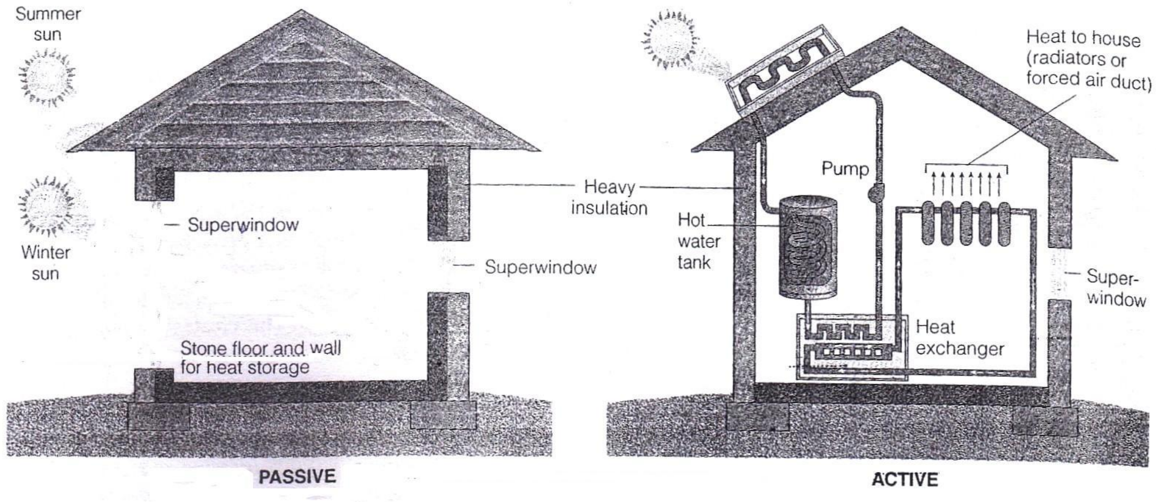


Figure 10.11: Passive and Active solar heating for a home

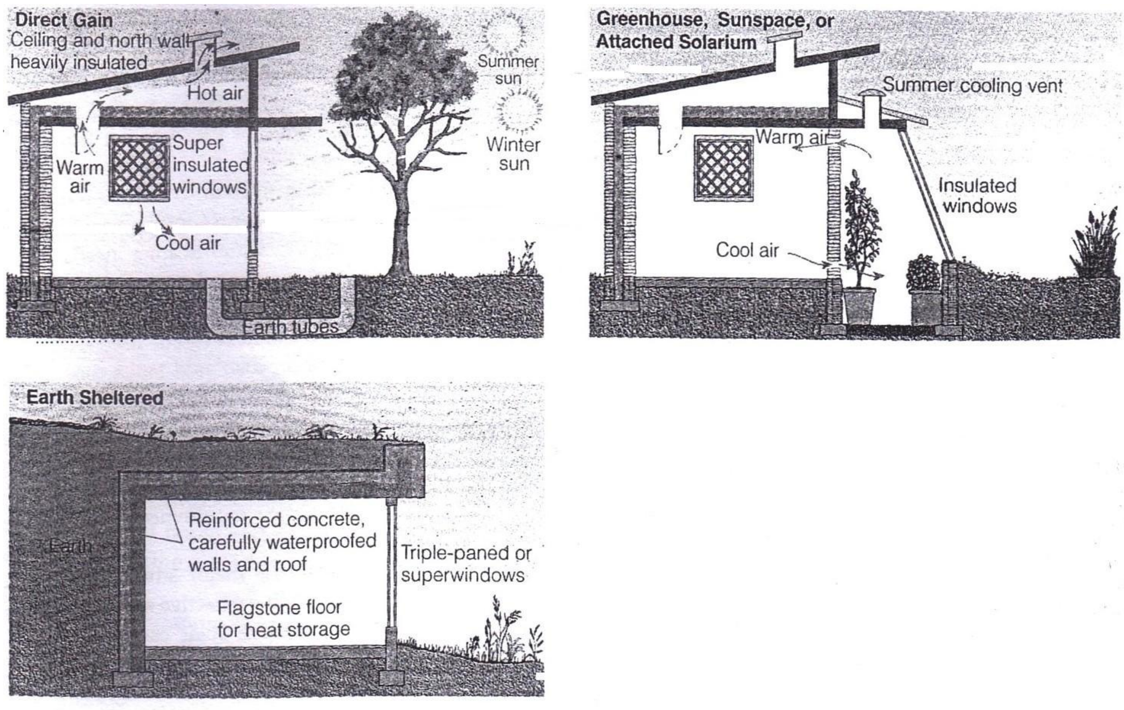


Figure 10.12: Solutions: Three examples of passive solar design for houses

On a life cycle cost basis, good-passive solar and super insulated design is the cheapest way to heat a home or small building in regions where ample sunlight is available during the daytime. **Figure 10.12** Such a system usually adds 5-10% to the construction cost, but the life cycle cost of operating such a house is 30-40% lower. The typical payback time for passive solar features is 3-7 years.

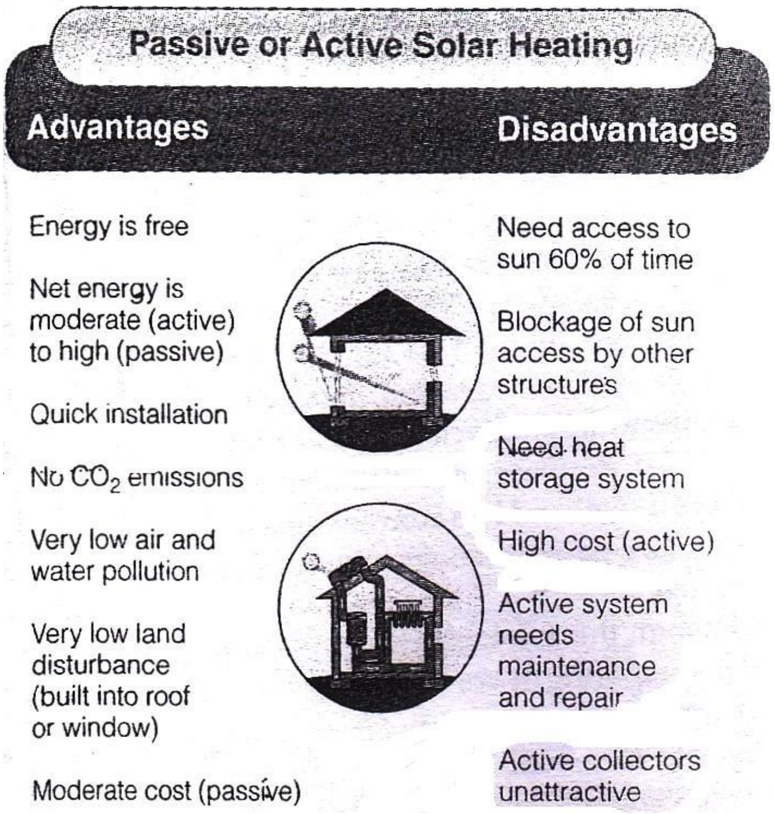


Figure 10.13: Trade offs: Advantages and disadvantages of heating a house with passive or active solar energy

In an active solar heating system, collectors absorb solar energy, and a fan or a pump supplies part of a building's space-heating or water-heating needs. Several connected collectors are usually mounted on the roof with an unobstructed exposure to the sun. Some of the heat can be used directly. The rest can be stored in insulated tanks containing rocks, water, or a heat-absorbing chemical for release as needed. Active solar collectors can also supply hot water. Most analysts do not expect widespread use of active solar collectors for heating houses because of high costs, maintenance requirements, and unappealing appearance.

Figure 10.13 lists the major advantages and disadvantages of using passive or active solar energy for heating buildings. Passive solar cannot be used to heat existing homes and buildings not oriented to receive sunlight or whose access to sunlight is blocked by other buildings and structures.

How Can We Cool Houses Naturally? Here are some ways to make a building cooler. Use super insulation and super insulating windows. Block the high summer sun with deciduous trees, window overhangs, or awnings (Figure 3.12, top left). Use windows and fans to take advantage of breezes and keep air moving. Suspend reflective insulating foil in an attic to block heat from radiating down into the house. Homeowners can also place plastic *earth tubes* 3-6 meters (10-20 feet) underground where the earth is cool year round. Then a tiny fan can pipe cool and partially dehumidified air into an energy-efficient house (Figure 3.12, top left). In dry climates building can be cooled by solar-powered evaporative air conditioners? However, they cost too much for residential use and do not work in humid climates.

How Can We Use Solar Energy to Generate High Temperature Heat and Electricity- Several so called solar thermal systems collect and transform radiant energy from the sun into high-temperature thermal energy (heat), which cart be used directly or converted to electricity. One method uses a central receiver system, called a power tower. Huge arrays of computer-controlled mirrors called *heliostats* track the sun and focus sunlight on a central heat collection tower (Figure 3.14, top drawing). By 2006, Australia is planning to build a power tower in its sunny outback that will be more than twice the height of the world's tallest building. Another approach is a solar thermal plant or distributed receiver system, in which sunlight is collected and focused on oil-filled pipes running through the middle of curved solar collectors (Figure 3.14, bottom drawing). This concentrated sunlight can generate temperatures high enough for industrial processes or for producing steam to run turbines and generate electricity. At night or on cloudy days, high-efficiency combined-cycle natural gas turbines can supply backup electricity as needed.

A different type of distributed receiver system uses parabolic dish collectors (which look somewhat like TV satellite dishes) instead of parabolic troughs. These collectors can track the sun along two axes and generally are more efficient than troughs. A pilot plant is being built in northern Australia. The DOE projects that within 10-20 years, parabolic dishes with a natural gas turbine backup should be able to produce electrical power costing about the same as that from coal-burning plants.

Inexpensive *solar cookers* can focus and concentrate sunlight and cook food especially in rural villages in sunny developing countries. They can be made by fitting an insulated box big enough to hold three or four pots with a transparent, removable top. Solar cookers reduce deforestation for fuel wood and the time and labor needed to collect firewood. They also reduce indoor air pollution from smoky fires. **Figure 10.14**

Figure 3.14 lists the advantages and disadvantages of concentrating solar energy to produce high-temperature heat or electricity. Most analysts do not expect widespread use of such technologies over the next few decades for several reasons. One is their high costs, and another is lack of sufficient tax breaks and government research and development funding. Finally, there are much cheaper ways to produce electricity such as combined-cycle natural gas turbines and wind turbines.

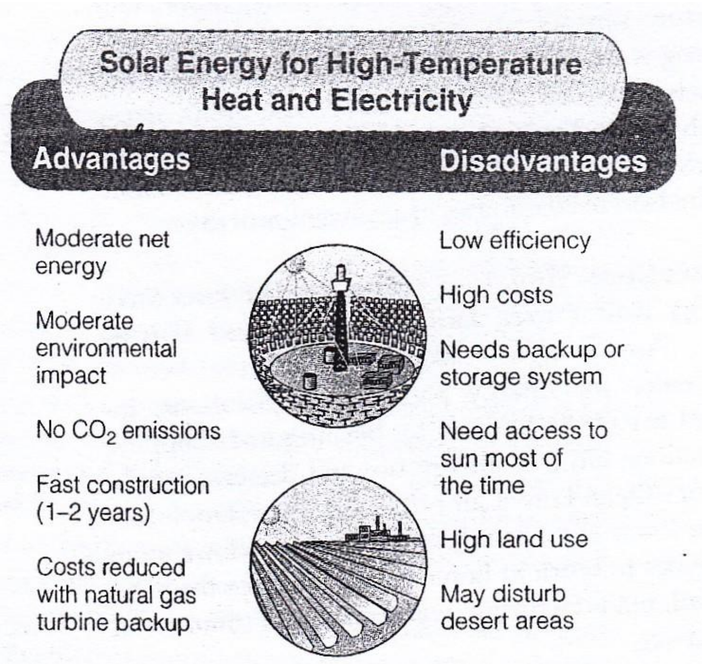


Figure 10.14: Trade offs: Advantages and disadvantages of using solar energy to generate high temperature heat and electricity

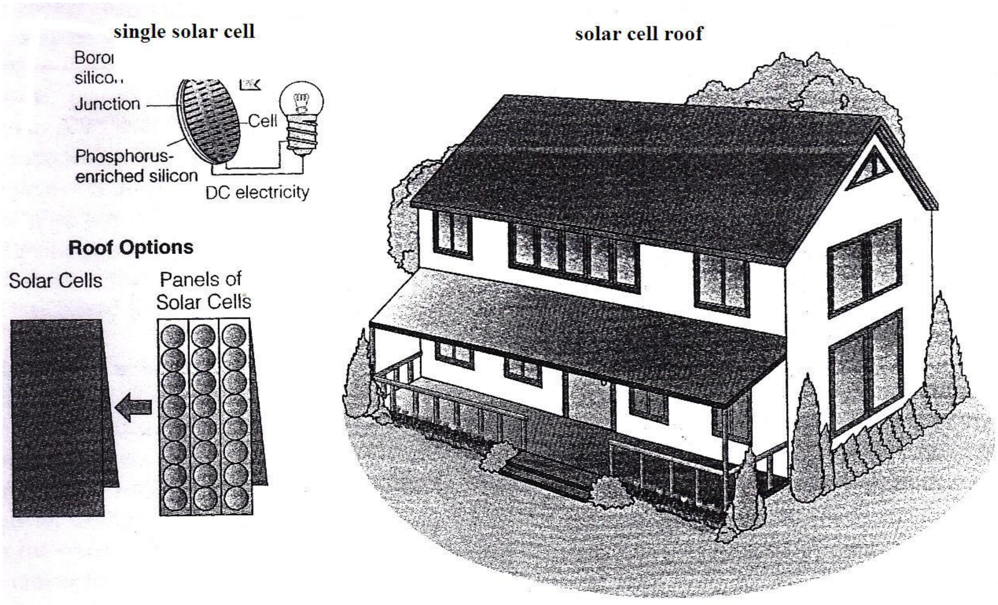


Figure 10.15: Solutions: photovoltaic (PV) (solar) cells can provide electricity for a house or building using new solar-cell roof shingles or PV panel roof systems that look like metal roofs. Arrays of such cells can also produce electricity for a village or at a small power plant

How Can We Produce Electricity with Solar Cells? Solar energy can be converted directly into electrical energy by photovoltaic (PV) cells, commonly called solar cells (Figure 10.15). A solar cell is a transparent wafer containing a *semiconductor* material with a thickness ranging from less than that of a human hair to that of a sheet of paper. Sunlight energizes and causes electrons in the semiconductor to flow, creating an electrical current.

A single solar cell produces only a tiny amount of electricity. Thus many cells are wired together in modular panels to produce the amount of electricity needed. The resulting direct current (DC) electricity can be stored in batteries and used directly. Another option is reconvert the-DC to conventional alternating current (AC) electricity by a separate inverter or an inverter built into the cells. Traditional looking solar-cell roof shingles and roofing material (developed in Japan) reduce the cost of solar-cell installations by saving on roof costs (Figure 3.15). Glass walls and windows of buildings can also have built-in solar cells. With this technology, the roof and glass walls and windows become a building's power plant.

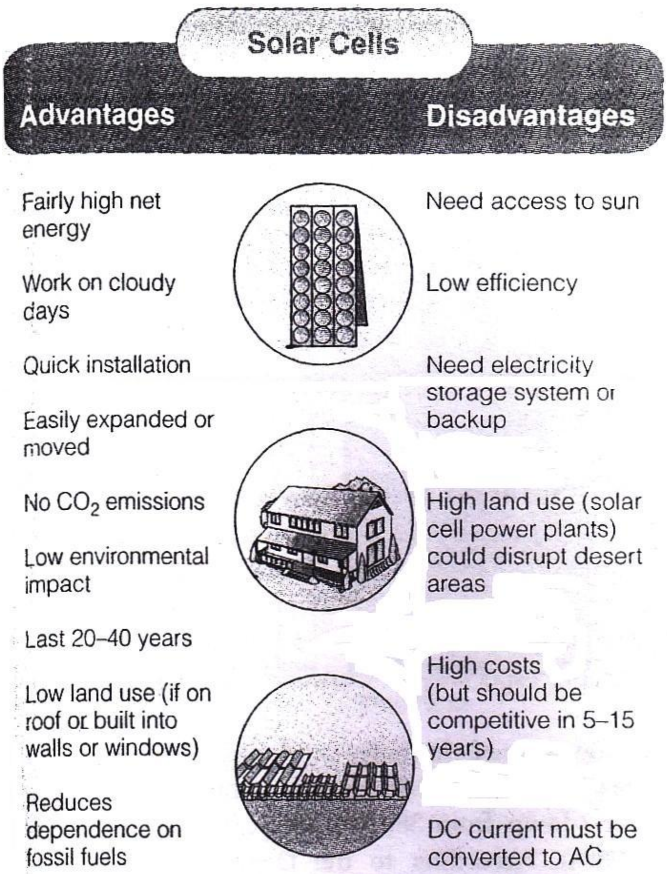


Figure 10.16: Trade offs: Advantages and Disadvantages of using solar cells to produce electricity

Easily expandable banks of solar cells can be used to provide electricity in developing countries for 1.7 billion people in rural villages that have no electricity. They can also produce electricity at a small power plant, using combined-cycle natural gas turbines to provide backup power when the sun is hot shining. Another possibility is to use arrays of solar cells to convert water to hydrogen gas that can be distributed to energy users by pipeline, as natural gas is With financing from the World Bank, India (the world's number-one market for solar cells) is installing solar-cell systems in 38,000 villages, and Zimbabwe is bringing solar electricity to 2,500 villages.

Figure 10.16 lists the advantages and disadvantages of solar cells. By 2003, more-than 1 million homes in the world (most of them in villages in developing countries and about 200,000 in the United States) were getting some or all of their electricity from solar cells. Current costs of producing electricity from solar cells are high (about 30c per kilowatt-hour). But costs are expected to drop because of savings from mass production of solar cells and greatly increased research by major corporations and many governments in solar-cell design.

With a strong push from governments and private investors, by 2050 solar cells could provide up to 25% of the world's electricity (and at least 35% in the United States). If such projections are correct, the production, sale, and installation of solar cells could become one of the world's largest and fastest growing businesses.

Producing electricity from moving water and from heat stored in water

How Can We Produce Electricity Using Hydropower Plants? Electricity can be produced from flowing water by three methods. *One* is large-scale hydropower, in which a high dam is built across a large river to create a reservoir. Some of the water stored in the reservoir is allowed to flow through huge pipes at controlled rates, spinning turbines and producing electricity.

Another method is small-scale hydropower. In this case a low dam with no reservoir (or only a small one) is built across a small stream, and the stream's flow of water is used to spin turbines and produce electricity

A *third* method is pumped-storage hydropower. First, pumps use surplus electricity from a conventional power plant to pump water from a lake or a reservoir to another reservoir at a higher elevation. When more electricity is needed, water in the upper reservoir is released, flows through turbines, and generates electricity on its return to the lower reservoir.

In 2001, hydropower supplied about 7% of the world's total commercial energy (2% in the United States), 20% of the world's electricity (6% in the United States but about 50% of the power used along the West Coast). It supplies 99% of the electricity in Norway, 75% in New Zealand, 50% in developing countries, and 25% in China.

Figure 10.17 lists the advantages and disadvantages of using large-scale hydropower plants to produce electricity. According to the United Nations, only about 13% of the world's exploitable potential for hydropower has been developed. Much of its untapped potential is in south Asia (especially China), South America, and parts of the former Soviet Union.

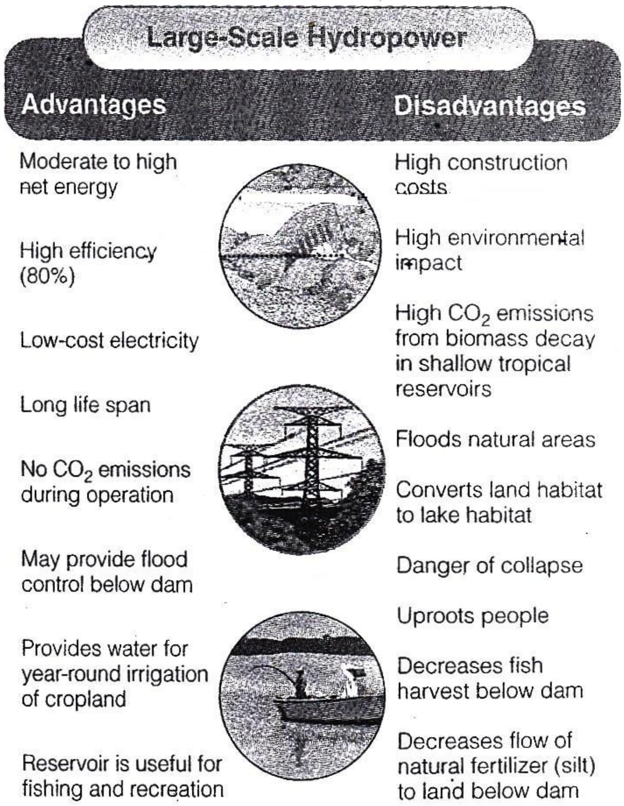


Figure 10.17: Trade offs: Advantages and Disadvantages of using large dams and reservoirs to produce electricty

Because of increasing concern about the harmful environmental and social consequences of large dams, there has been growing pressure on the World' Bank and other development agencies to stop funding new large-scale hydropower projects. According to a 2000 study by the World Commission on Dams, hydropower in tropical countries is a major emitter of greenhouse gases. This occurs because reservoirs that power the dams can trap rotting vegetation, which can emit greenhouse gases such as $C0_2$ and CH_4. Small-scale hydropower projects eliminate most of the harmful environmental effects of large-scale projects. However, their electrical output can vary with seasonal changes in stream flow.

Is Producing Electricity from Tides and Waves a Useful Option? Twice a day in high and low tides, water that flows into and out of coastal bays and estuaries can spin turbines to produce electricity. Two large tidal energy facilities are currently operating, one at the Rance estuary in France and the other in Canada's Bay of Fundy. Most analysts expect tidal power to make only a tiny contribution to world electricity supplies because of a lack of suitable sites and high construction costs. The kinetic energy in ocean waves created primarily by wind is another potential source of electricity. Most analysts expect wave power to make little contribution to world electricity production, except in a few coastal areas with the right conditions (such as western England).

How Can We Produce Electricity from Heat Stored in Water? Japan and the United States have been evaluating the use of the large temperature differences between the cold deep waters and the sun-warmed surface waters of tropical oceans for producing electricity. If economically feasible, this would be done *in ocean thermal energy conversion (OTEC)* plants anchored to the bottom of tropical oceans in suitable sites. However, most energy analysts believe the large-scale extraction of energy from ocean thermal gradients may never compete economically with other energy alternatives.

Saline solar ponds, usually located near inland saline seas or lakes in areas with ample sunlight, can be used to produce electricity. Heat accumulated during the day in the denser bottom layer can be used to "produce steam that spins turbines, generating electricity. A small experimental power plant on a saline solar pond on the Israeli shore of the Dead Sea operated for several years but was closed in 1989 because of high operating costs.

Freshwater solar ponds can be used to heat water and space. A shallow hole is dug and lined with concrete. A number of large black plastic bags, each filled with several centimeters of water, are placed in the hole and then covered with fiberglass insulation panels. The panels let sunlight in but keep most of the heat stored in the water during the daytime from being lost to the atmosphere. Typically, the water in the bags reaches its peak temperature in the afternoon. Then a computer turns on pumps that transfer hot water from the bags to large insulated tanks for distribution

Saline and freshwater solar ponds use no[1] energy storage and backup systems, emit no air pollution, and have a moderate net energy yield. Freshwater solar ponds can be built in almost any sunny area and have moderate construction and operating costs. However saline and freshwater solar ponds are expected to make little contribution to global energy supplies in the foreseeable future.

Producing electricity from wind

What Is the Status of Wind Power? In 2002, wind turbines (Figure 10.18) worldwide produced more than 32,000 megawatts of electricity, enough to meet the residential needs of 35 million people worldwide. About 73% of the world's wind power is produced in Europe, especially in Germany, Spain, and Denmark.

In 2002, the price of electricity produced by wind at prime sites in the United States was about 4(f per kilowatt-hour (down from 38c. per kilowatt-hour in the early 1980s). According to the Department of Energy, this is almost equal to the cost of electricity produced by new coal-fired power plants and half the cost if coal's health and environmental costs are included. This is also about half the cost of nuclear power if all nuclear fuel cycle costs are taken into account. Increased investments in wind power by governments and large corporations should reduce its costs further as a result of technological innovations and savings from mass production of wind turbines.

What Areas Have the Greatest Potential for Wind Power? In 2002, western European countries produced 2% of their electricity from wind (18% in Denmark). These countries expect to get at least 10% if their electricity from onshore and offshore wind turbines within 10 years. The German government plans to get 25% of its electricity from wind power by 2025 (up from 4.7% in 2002), much of it from building offshore wind farms in the Baltic and the North Sea.

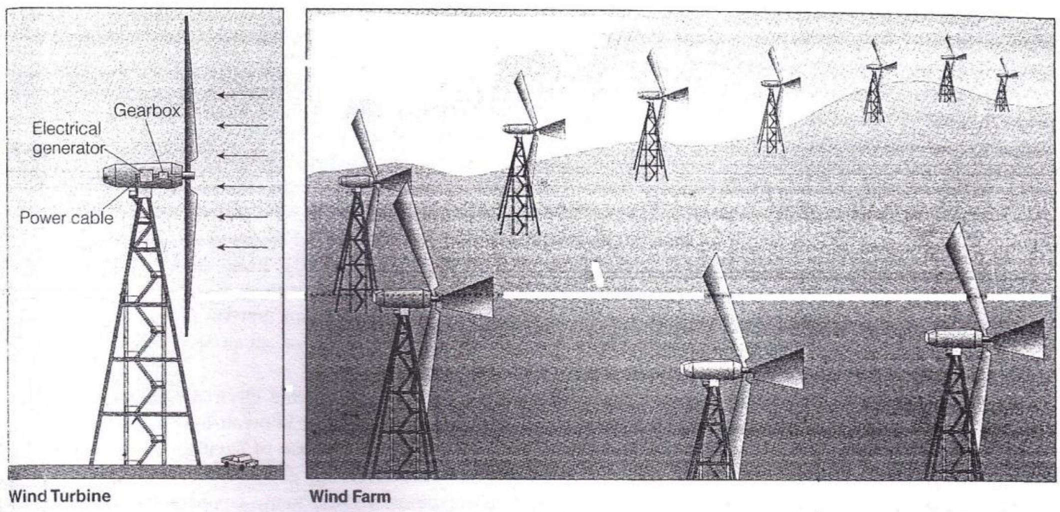


Figure 10.18: Solutions; wind turbines, which can be used to produce electricity individually or in clusters, called wind farms. Since 1990, wind power has been the world's fastest growing source of energy

Wind power is also being developed rapidly in India (the world's number-two market for wind energy), and China could easily double its wind-generating capacity. Figure 10.19 shows the potential areas for use of wind power in the United States. Currently, wind power supplies less than 0.5% of America's electricity (enough to power more than 1.3 million homes) but 1.5% of California's electricity. However, the DOE cans the mid western United States the "Saudi Arabia of wind." The Dakotas and Texas alone have enough wind resources to me*et al.*,l the nation's electricity needs.

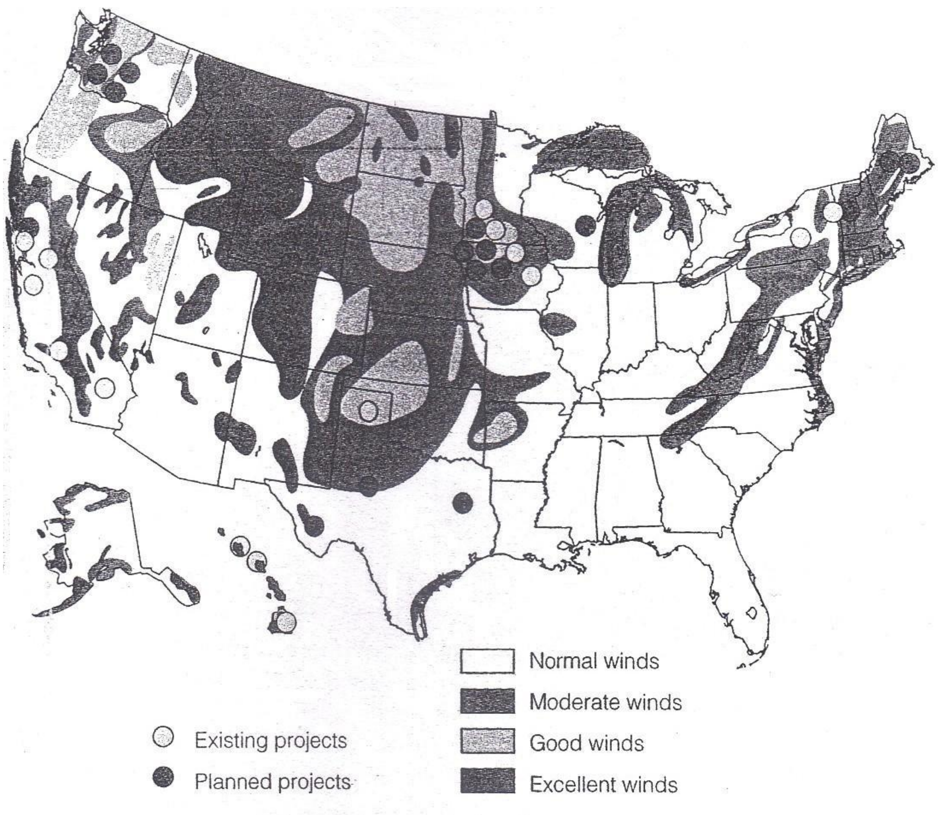


Figure 10.19: Solutions: potential for use of wind power in the United States. In principle, exploiting the wind potential of just three states—North Dakota, South Dakota, and Texas—could provide all the Power nee'ds of the United States. (Data from U.S. Department of Energy)

According to the American Wind Energy Association, the United States could use wind power to produce 23% of its electricity by 2025. A growing number of U.S. farmers and ranchers boost their income by leasing some of their cropland or ranchland for wind turbines while still growing crops or grazing cattle around the turbines. Currently a U.S. farmer or rancher who leases 0.10 hectare (0.25 acre) of cropland or rangeland to the local utility as a site for a wind turbine can easily get $2,000 a year in royalties from providing the local community with electricity worth $100,000. Some are making more money by leasing their land for wind power production than by growing crops or raising cattle. This explains why many U.S. farmers and ranchers are joining environmentalists and wind industry executives in urging political leaders to increase government research and development and tax breaks for wind power.

What Are the Major Advantages and Disadvantages of Wind Power? Figure 10.20 lists the advantages and disadvantages of using wind to produce electricity. Some critics have alleged that wind turbines suck large numbers of birds into their wind stream. However, as long as wind farms are not located along bird migration routes most birds learn to fly around them.

Also, studies have shown that much .larger numbers of birds die when they are sucked into jet engines, killed by domesticated and feral cats, and crash into skyscrapers, plate glass windows, communications towers, and car windows.

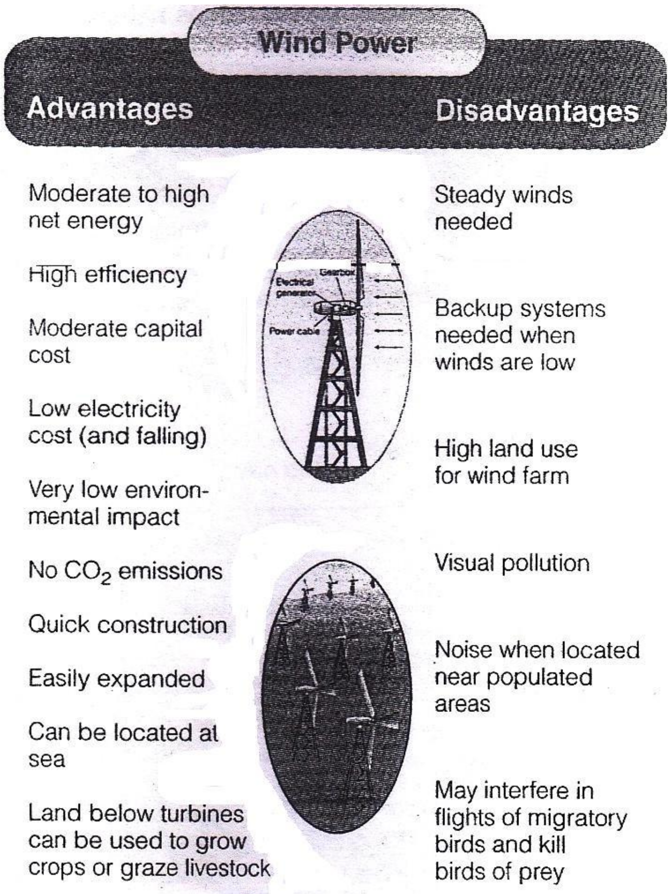


Figure 10.20: Trade offs: advantages and disadvantages of using wind to produce electricity. Wind power experts project that by 2020 wind power could supply more than 10% of the world's electricity and 10-25% of the electricity used in the United States

Even larger numbers of birds, fish, and other forms of wildlife are killed by oil spills, air pollution, water pollution and release of toxic wastes from use of fossil fuels such as coal and oil. The key Questions are which types of energy resources lead to the lowest loss of wildlife and how we can minimize loss of wildlife from use of any energy resource.

In the long run, electricity from large wind farms in remote areas might be used to make hydrogen gas from water during off-peak periods—thus storing electricity from excess wind capacity in a useful fuel. The hydrogen could then be fed into a pipeline and storage system for fuel cells or gas turbines used to power cars, homes, and buildings. Increasingly, many governments and corporations are recognizing that wind is a vast, climate-Benign, renewable energy resource that can supply both electricity and hydrogen fuel at an affordable cost. If its current growth, rate continues, wind power could produce 10% of the world's electricity by 2020.

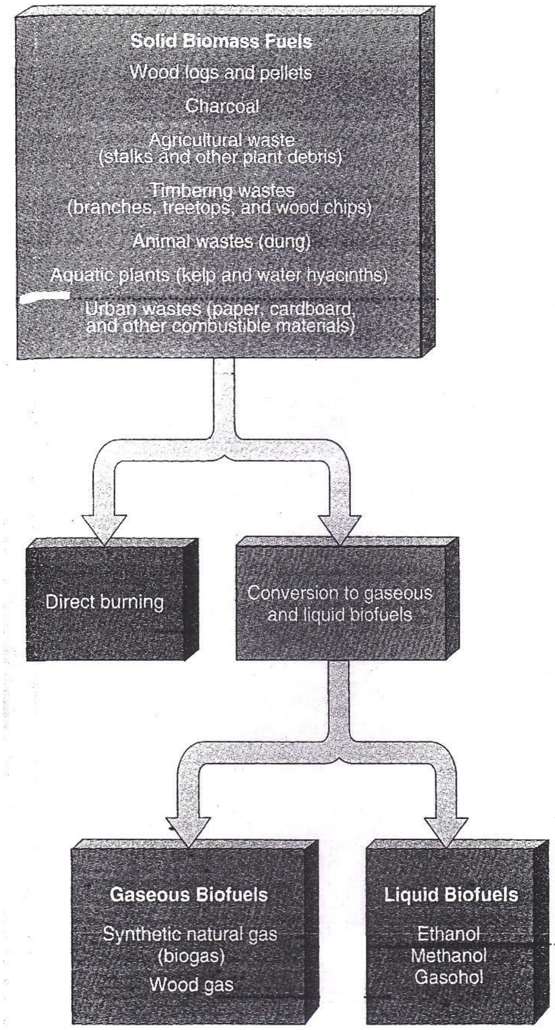


Figure 10.21: Principal types of biomass fuel

Producing energy from biomass

How Useful Is Burning Solid Biomass? Bio-mass consists of plant materials and animal wastes used as sources of energy. Biomass comes in many forms and can be burned directly as a solid fuel or converted into gaseous or liquid biofuels (Figure 10.21).

Most biomass is burned *directly* for hearing, cooking, and industrial processes or *indirectly* to drive turbines and produce electricity. Burning wood and manure for heating and cooking supplies about 11% of the world's energy and about 30% of the energy used in developing countries. Almost 70% of the people living in developing countries heat their homes and cook their food by burning wood or charcoal. However, about 2.7 billion people in these countries cannot find or are too poor to buy enough fuel wood to meet their needs.

In the United States, biomass is used to supply about 4% of the country's commercial energy and 2% of its electricity (produced by about 350 biomass power plants). The U.S. government has a goal of increasing the use of biomass energy to 9% of the country's total commercial energy by 2010. One way to produce biomass fuel is to plant, harvest, and burn large numbers of fast-growing trees (especially cottonwoods, poplars, sycamores, willows, and leucaenas), shrubs, perennial grasses (such as switchgrass), and water hyacinths in *biomass plantations.*

In agricultural areas, *crop residues* (such as sugar-: cane residues, rice husks, cotton stalks, and coconut shells) and *animal manure* can be collected and burned or converted into biofuels. According to a 1999 study by the Union of concerned Scientists, energy crops and crop wastes from the Midwest alone could theoretically provide about 16% of the electricity used in the United States, without irrigation and without competing with food crops for land. Some ecologists argue that it makes more sense to use animal manure as a fertilizer and crop residues to feed livestock, retard soil erosion, and fertilize the soil.

Figure 3.22 lists the general advantages and disadvantages of burning solid biomass as a fuel. One problem is that burning biomass produces $C0_2$. How- -ever, if the rate of use of biomass does not exceed the rate at which it is replenished by new plant growth (which takes up $C0_2$), there is no net increase in $C0_2$ emissions.

Is Producing Gaseous and Liquid Fuels from Solid Biomass a Useful Option? Bacteria and various chemical processes can convert some forms of biomass into gaseous and liquid biofuels (Figure 10.22). Examples include *biogas* (a mixture of 60% -methane and 40% $C0_2$), *liquid ethanol* (ethyl, or grain, alcohol), and *liquid methanol* (methyl, or wood alcohol). In rural China, anaerobic bacteria in more than 6 million *biogas digesters* convert plant and animal wastes into methane fuel for heating and cooking. These simple devices can be built for about $50 including labor.

In the United States, livestock wastes are converted to biogas by bacteria by placing the wastes in a long, lined, insulated pit. A flexible liner stretching across the digester pit inflates like a balloon as it collects the biogas. The biogas may be used to heat the digester or nearby farm buildings or to produce electricity. Some analysts believe liquid ethanol and methanol, produced from biomass could replace gasoline and diesel fuel when oil becomes too scarce and expensive. Ethanol can be made from sugar and grain crops (sugarcane, sugar beets, sorghum, sunflowers, and corn) by fermentation and distillation. Gasoline mixed with 10-23% pure ethanol makes *gasohol,* which can be burned in conventional gasoline engines and is sold as super unleaded or ethanol-enriched gasoline. Figure 10.23 lists the advantages and disadvantages of using ethanol as a vehicle fuel.

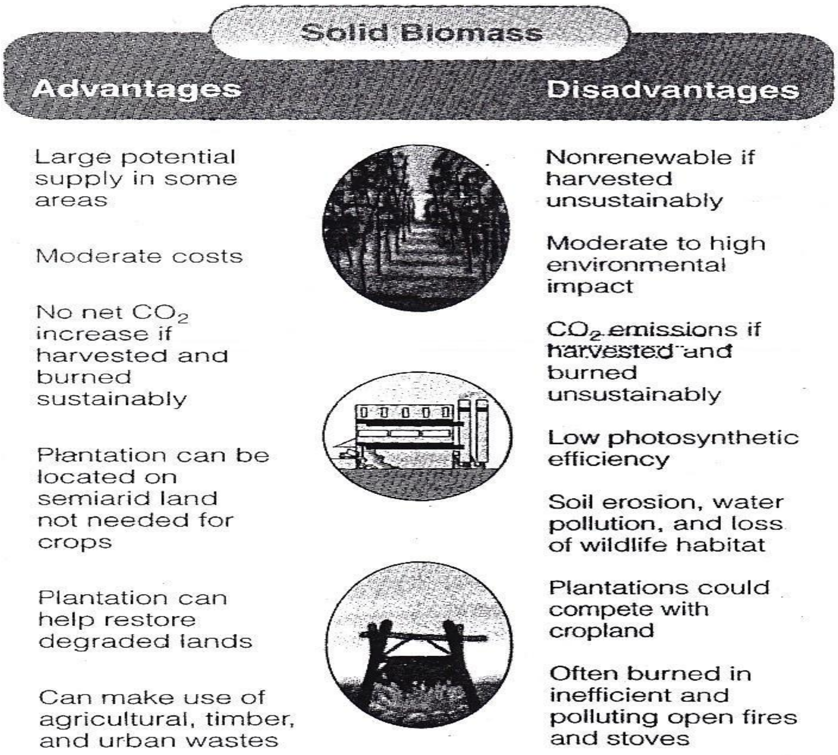


Figure 10.22: Trade offs: General advantages and disadvantages of burning slid biomass as a fuel

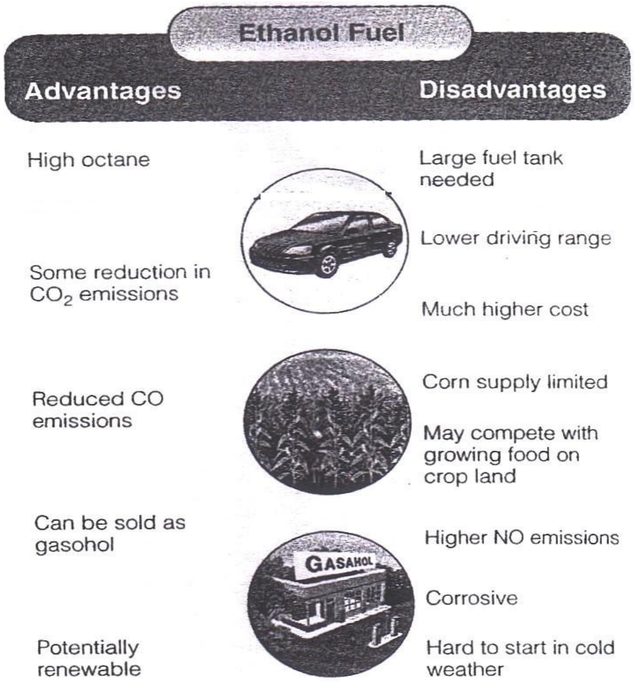


Figure 10.23: Trade offs: General advantages and Diaadvantages of using ethanol as a vehicle fuel

Another alcohol, *methanol*, is made mostly from natural gas but also can be produced at a higher cost from wood, wood wastes, agricultural wastes (such as corncobs), sewage sludge, garbage, and coal. Some of the first generation of cars using hydrogen-powered fuel cells will use reformers to convert carbon-containing natural gas, gasoline, or methanol to hydrogen. According to a 1997 analysis by David Pimentel and two other researchers, Large-scale biofuels production is not an alternative to the current use of oil and is not even an advisable option-to cover a significant fraction of it.

The solar-hydrogen revolution

What Can We Use to Replace Oil? Good bye Oil and Smog, Hello Hydrogen When oil is gone (or when what is left costs too much to use), how will we fuel vehicles, industry, and buildings? Many scientists and executives of major oil companies and automobile companies say the fuel of the future is hydrogen gas (H_2)—envisioned in 1874 by science fiction writer Jules Verne in his book *The Mysterious Island.*

When hydrogen gas burns in air it combines with oxygen gas in the air and produces nonpolluting water vapor ($2\ H_2 + 0_2 \rightarrow 2\ H_2O$). Widespread use of this fuel would eliminate most of the air pollution problems we face today. It would also greatly reduce the threat from global warming by emitting no $C0_2$ as long as the hydrogen is not produced from fossil fuels r other carbon containing compounds. The *bad news* is that although hydrogen is all around us it is chemically locked up in water and organic compounds such as methane and gasoline. The *'good news* is that we can produce it from something we have plenty of water. Water can be split by electricity electrolysis) or high temperatures (thermolysis) into gaseous hydrogen and oxygen.

There are other ways to produce hydrogen. One is reforming, in which higher temperatures and chemical- processes are used to separate hydrogen from carbon atoms in organic chemicals (hydrocarbons) found in conventional carbon-containing fuels such as natural gas, gasoline, or methanol. Gasification of coal (Figure 3.49) or biomass can also produce it other sources are decomposition of sewage sludge and other wet biomass and some types of algae and bacteria (Spotlight). These various sources of hydrogen could become, as some scientists put it, "tomorrow's oil." The resulting hydrogen could be used to provide most of the energy needed to run an economy.

Producing hydrogen from green algae found in pond scum

When living in ordinary air and sunlight, green algae carry out photosynthesis like other plants and produce carbohydrates and oxygen gas. However, in 2000, Tasios Melis, a researcher at the University of California at Berkeley, found a way to make these algae produce bubbles of hydrogen rather than oxygen.

First, he grew cultures of hundreds of billions of the algae in the normal way with plenty of sunlight, nutrients, and water. Then he cut off their supply of two key nutrients: sulfur and oxygen. Within 20 hours, the plant cells underwent a metabolic change and switched from an oxygen-producing to a hydrogen-producing metabolism, allowing the researcher to collect hydrogen gas bubbling from me culture.

Melis believes he can increase the efficiency of this hydrogen-producing process tenfold. If so, sometime in the future a biological hydrogen plant might cycle a mixture of algae and water through a system of Clear tubes exposed to sunlight to produce hydrogen. The gene responsible for producing the hydrogen might even be transferred to other plants to produce hydrogen.

What Is the Catch? If you think using H_2 as the world's major energy source sounds too good to be true, you are right. Several problems must be solved to make hydrogen one of our primary energy resources, but scientists are making rapid progress in finding solutions to these challenges.

One problem is that it takes energy (and thus money) to produce this fuel. We could bum coal or synthetic natural gas (Figure 3.49) to produce high-temperature heat or use electricity from coal-burning and conventional nuclear power plants to split water and produce hydrogen. However, these subjects we to the harmful environmental effects associated with using these fuels (Figure 3.48; Figure 3.50; Figure 3.53; and Figure 3.54) this also costs more than the hydrogen fuel is worth when environmental costs are included.

Producing hydrogen by coal gasification or from carbon-containing methane (natural gas), gasoline methanol (reforming) can be used. However, according to a 2002 article by physicist Marin Hotter and a team of other scientists, this adds more $C0_2$ to the atmosphere per unit of heat generated than does burning these carbon-containing fuels directly. Thus doing this could accelerate global warming:

In 2003, environmentalists were pleased that President Bush talked about the benefits of a hydrogen economy and proposed spending $1.7 billion over the following two to five years to build partnerships with the private sector to develop new vehicle and fuel technologies and the infrastructure needed to make it practical and cost-effective for large numbers of Americans to choose fuel cell vehicles by 2020. Such a program would also dramatically improve America's energy security by significantly reducing the need for imported oil, reduce air pollution, and also reduce emissions of carbon dioxide. However, environmentalists were disappointed that President Bush's proposals relied mostly on generating the hydrogen from carbon-containing fuels, which produce carbon dioxide instead of placing more emphasis on using renewable energy resources to produce hydrogen fuel.

Most proponents of using hydrogen gas believe that if we are to get its very low pollution benefits, the energy to produce H_2 by decomposing water must come from low polluting, renewable sources. The most likely sources are electricity generated by solar cells, wind farms, hydropower, and geothermal energy, or biological process in bacteria and algae (Spotlight, left). The type of renewable energy used would vary in different parts of the world depending on its local and regional availability. Another possibility is to use electricity or heat produced by nuclear fusion power plants to decompose water if this energy alternative turns out to be technologically and economically feasible.

If scientists and engineers can learn how to use various forms of direct and indirect solar energy to decompose water cheaply enough, they will set in motion a *solar-hydrogen revolution* over the next 50—l00 years and change the world as much as the agricultural and industrial revolutions did. In effect, the world would shift from carbon-based *fossil fuel economies* (Figure 3.33) to decarbonized *hydrogen economies*, powered increasingly by using solar energy (or perhaps nuclear fusion) to produce hydrogen gas from water (Figure 3.35). By using renewable solar energy, such an economy would follow the first of the four principles of sustainability based on observing how the earth sustains itself.

Methane from natural gas may be used to produce hydrogen in the transition to a true renewable hydrogen system because of its large supply and lower production of air pollutants and $C0_2$ (Figure 3.41) compared to other fossil fuels. How Can We Store Hydrogen? Once hydrogen is produced we must have a way to store it for use as needed one way is to store it m *compressed gas tanks* either above or below ground or aboard motor vehicles. Because of their large size and weight, such storage tanks have been more useful for buses and large trucks than for cars. However, in 2002, General Motors developed a lightweight, high-pressure, hydrogen storage tank that can be used on cars and can store enough hydrogen to provide a range of nearly 480 kilometers (300 miles) before refueling.

Another storage option is to convert hydrogen gas to more dense *liquid hydrogen.* This allows a larger quantity of hydrogen to be stored in stationary containers or aboard motor vehicles. However, the liquid (hydrogen must be stored at very low temperatures, below —250°C (—420°F). This is costly, takes a large input of energy (as much as 30% of the hydrogen's original fuel energy), and requires a large amount of insulation. Hydrogen can also be stored in *solid metal hydride compounds.* When cooled, certain metals absorb and chemically bond the hydrogen in the metal's lattice work of atoms. Heating the metal hydride compound releases the hydrogen gas as needed. This is a safe and efficient way to store hydrogen. But current metal hydrides are costly, heavy, and require energy to release the hydrogen.

Another possibility is to absorb H_2 on activated charcoal or graphite nano fibers hydrogen gas. Like hydrides, this is a safe and efficient way to store hydrogen, but an input of energy is needed to release the hydrogen. Hydrogen gas can also be stored *inside tiny glass microspheres.* In 2002, scientists were also able to trap hydrogen gas in a framework of water molecules called *clathrate hydrates*. Some *good news* is that metal hydrides, charcoal powders, graphite nanofibers, and glass microspheres containing hydrogen will not explode or burn if a vehicle's tank is ruptured in an accident. Such tanks would be much safer than current gasoline tanks.

What Is the Role of Fuel Cells in the Solar-Hydrogen Revolution? In a *fuel cell* (Figures 3.3), hydrogen and oxygen gas combine to produce electrical current. Various versions of such cells can be used to power a car or bus and to meet the heating, cooling, and electrical needs of buildings. Fuel cells have energy efficiencies of 65-95%. This is several times the efficiency of conventional gasoline-powered engines and electric cars and at least twice the efficiency of coal-burning and nuclear power plants. Fuel cells have no moving parts and are quiet. They emit only water and heat (and some $C0_2$ if the hydrogen is produced from carbon-containing substances such as gasoline, natural gas, propane, or methanol). Also fuel cells are more reliable than the traditional electricity grid because they are not as susceptible to lightning strikes, fallen trees, and terrorist or military attacks.

Some fuel cells are tiny enough to fit into a cellular phone. Others are big enough to power a large building or factory. Smaller fuel cells can power bicycles, vacuum cleaners, laptop computers, lawn mowers, leaf blowers, and other devices. With hydrogen-powered fuel cells, people would have their own personal power plant to run their lights, appliances, and car and to heat and cool their house. Here is some *good news.* A number of prototype fuel-cell systems for cars, buses, homes, and buildings are being tested and evaluated. Fleets of hydrogen powered buses are running in various cities of the world. In 1999, DaimlerChrysler, Royal Dutch Shell, and Norsk Hydro announced government-approved plans to turn the tiny country of Iceland into the world's first "hydrogen economy" by 2030-2040—the brainchild of chemist Bragi Arnason, known as Professor Hydrogen.

The country's abundant renewable geo-thermal energy, hydropower, and offshore winds will be used to produce hydrogen from seawater and the H_2 will be used to run its buses, passenger cars, fishing vessels, and factories. Royal Dutch Shell is already opening hydrogen filling stations in parts of Europe and plans to open a chain of such stations in Iceland. The first hydrogen filling station in the United States opened in Las Vegas, Nevada, in 2002.

The key problem with fuel cells so far is cost. For widespread use of fuel cells the price must be sharply reduced by improved technology and mass production. With greatly increased private and government-funded research and tax breaks, some analysts see this happening within 10 years. They envision fuel cells being used first by electric utilities, followed in order by midsize buildings, homes and small buildings, and motor vehicles. Some *good news* is that in 2002 researchers at the Lawrence Berkeley National Laboratory developed a solid oxide fuel cell (SOFC) that promises to generate electricity at one-tenth the cost of today's fuel cells and as cheaply as the most efficient gas turbine.

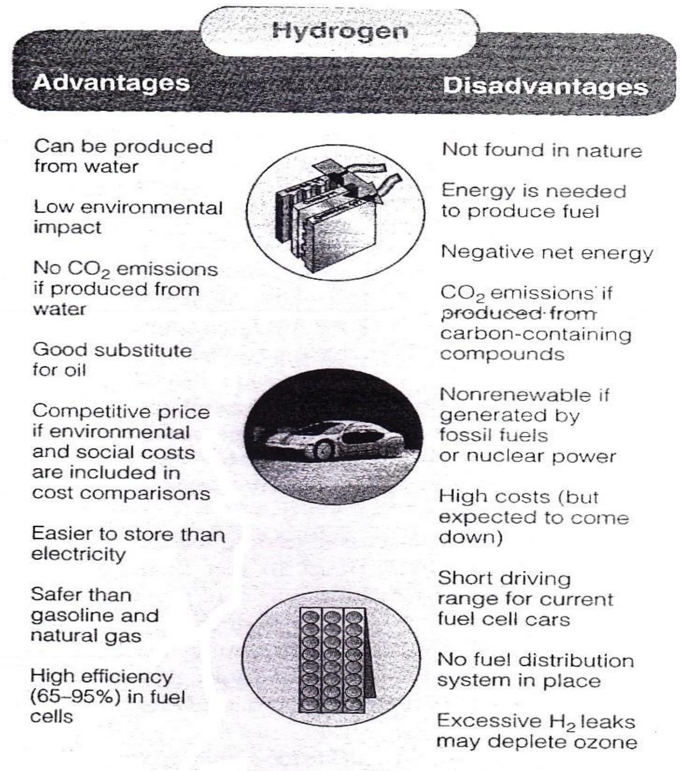


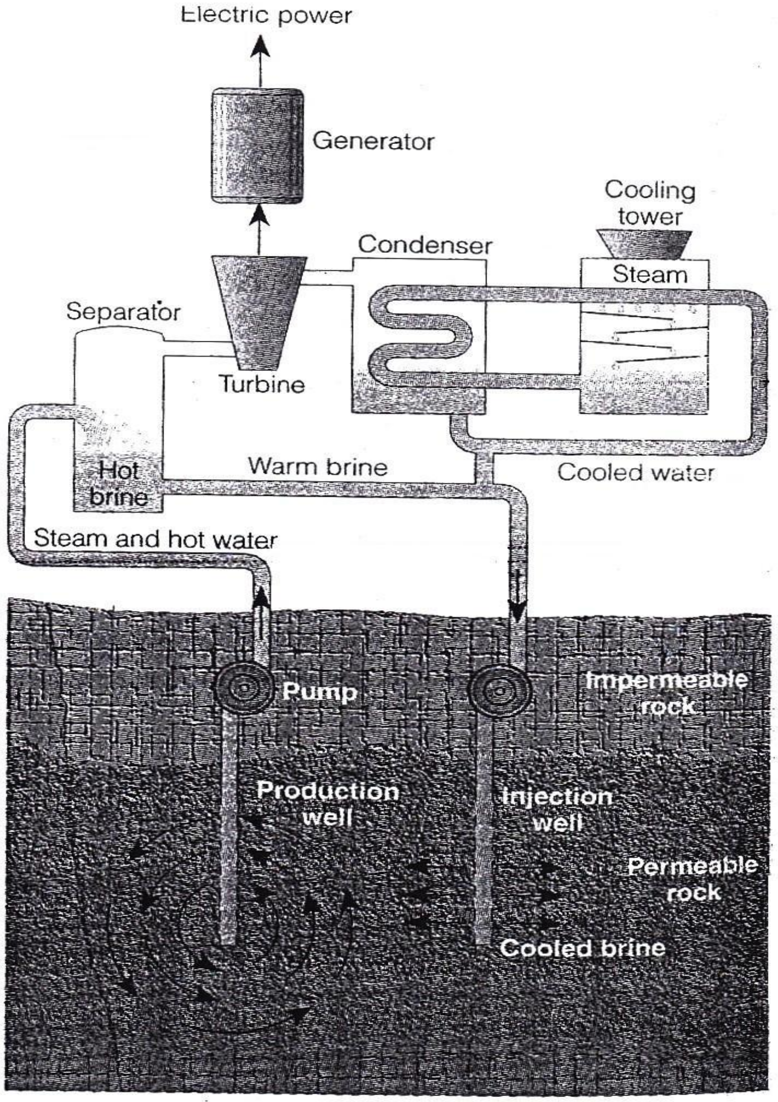
Figure 10.24: Trade offs: Advantages and Disadvantages of using hydrogen as a fuel for vehicles and for providing heat and electricity

What Are the Advantages and Disadvantages of Hydrogen as an Energy Resource? Figure 10.24 lists the advantages and disadvantages of using hydrogen as an energy resource. The U.S. Department of Energy has a goal of hydrogen energy providing 10% of all U.S. energy consumption by 2025.

Geothermal energy

How Can We Tap the Earth's Internal Heat?

Heat contained in underground rocks and fluids is an important source of energy. Over millions of years, this geothermal energy from the earth's mantle has been transferred to three types of underground reservoirs. One contains *dry steam,* which consists of steam with no water droplets. Another is *wet steam,* which consists of a mixture of steam and water droplets. The third is *hot water* trapped in fractured or porous rock at various places in the earth's crust.



Fihure 10.25: Solutions: Tapping the earth,s internal heat or geothermal energy in the form of wet steam to produce electricity

If such-geothermal sites are close to the surface, wells can be drilled to extract the dry steam, wet steam (Figure 10.25), or hot water. This thermal energy can be used to heat homes and buildings and to produce electricity. For example, geothermal energy is used to heat about

85% of Iceland's buildings. Currently, about 22 countries (most of them in the developing world) are extracting energy from geothermal sites to produce about 1% of the world's electricity. Japan, with an abundance of geothermal energy could get an estimated 30% of its electricity from this energy resource.

Geothermal electricity meets the electricity needs of 6 million 'Americans and supplies 6% of California's electricity. The world's largest operating geothermal system, called *The Geysers,* extracts energy from a dry steam reservoir north of San Francisco, California. But heat is being withdrawn from this geothermal site about 80 times faster than it is being replenished, converting this renewable resource to a nonrenewable source of energy. In 1999, Santa Monica, California, became the first city in the world to g*et al.*,l its electricity from geothermal energy.

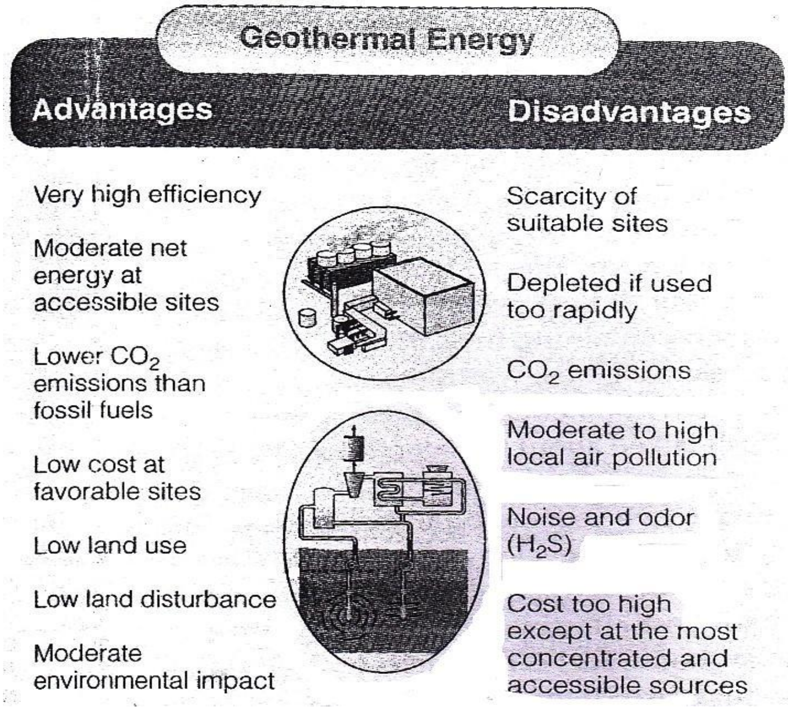


Figure 10.26: Trade offs: Advantages abd Disadvantages of geothermal energy for space heating and to produce electricity or high temperature heat for industrial processes

There are three other nearly nondepletable sources of geothermal energy. One is *molten rock* (magma). Another is *hot dry-rock zones,* where molten rock that has penetrated the earth's crust heats subsurface rock to high temperatures. A third source is low- to moderate-temperature *warm-rock reservoir deposits.* Heat from such deposits could be used to preheat water and run heat pumps for space heating and air conditioning. Hot dry-rock zones can be found almost anywhere about 8-10 kilometers (5-6 miles) below the earth's surface. Research is being carried out in several countries to see whether these zones can provide affordable geothermal energy.

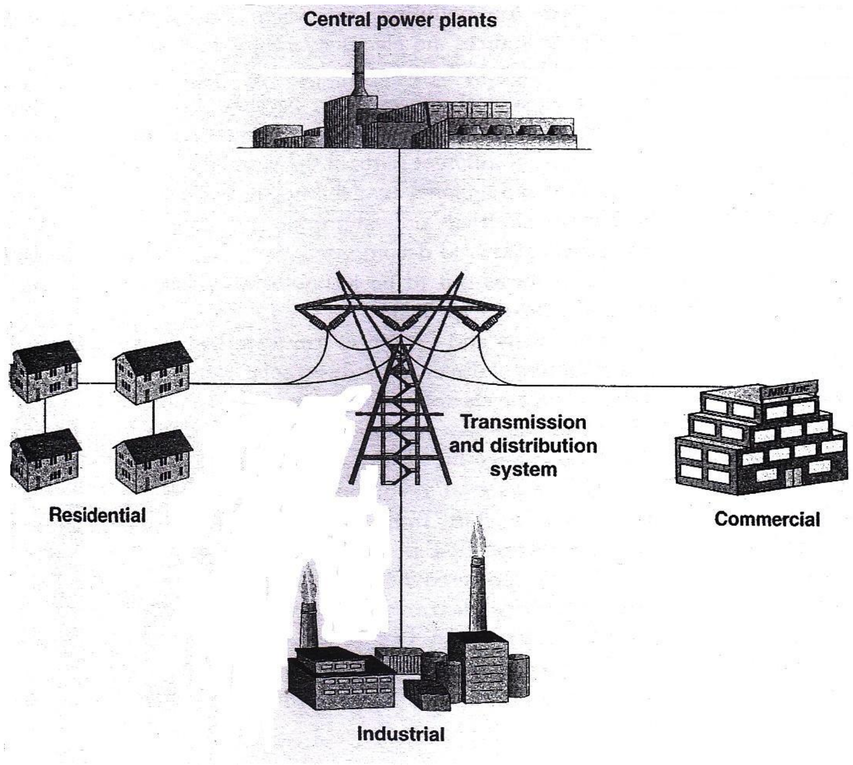


Figure 10.27: ***Centralized power system*** **in which electricity produced mainly by a fairly small number of large coal-burning and nuclear power plants (producing 600,000 to 1 million kilowatts of power) and natural gas turbines.(producing about 200,000 kilowatts of power) is distributed by a system of high-voltage wires to users. Such centralized systems are easy targets and make a country more vulnerable to widespread power outages and releases of radioactivity from terrorist or military attacks**

Figure 10.26 lists the advantages and disadvantages of using geothermal energy. Currently, the cost of tapping geothermal energy is too high for all but .the most concentrated and accessible sources. In 2000, the U.S. Department of Energy launched a program to have geothermal energy produces 10% of the electricity used in the western United States by 2020.

Entering the age of decentralized micropower

What Is Micro power? According to the director of energy supply policy for the Edison Electric Institute, Chuck Linderman, and the era of big central power plant systems (Figure 10.27) is over. Most energy analysts believe the chief feature of electricity production over the next few decades will be *decentralization* to dispersed, small-scale, micro power systems that generate 1-10,000 kilowatts of power (Figure 10.28) this shift from centralized *macropower* to dispersed *micropower* is analogous to the computer industry's shift from large centralized mainframes to increasingly smaller, widely dispersed PCs, laptops, and handheld computers.

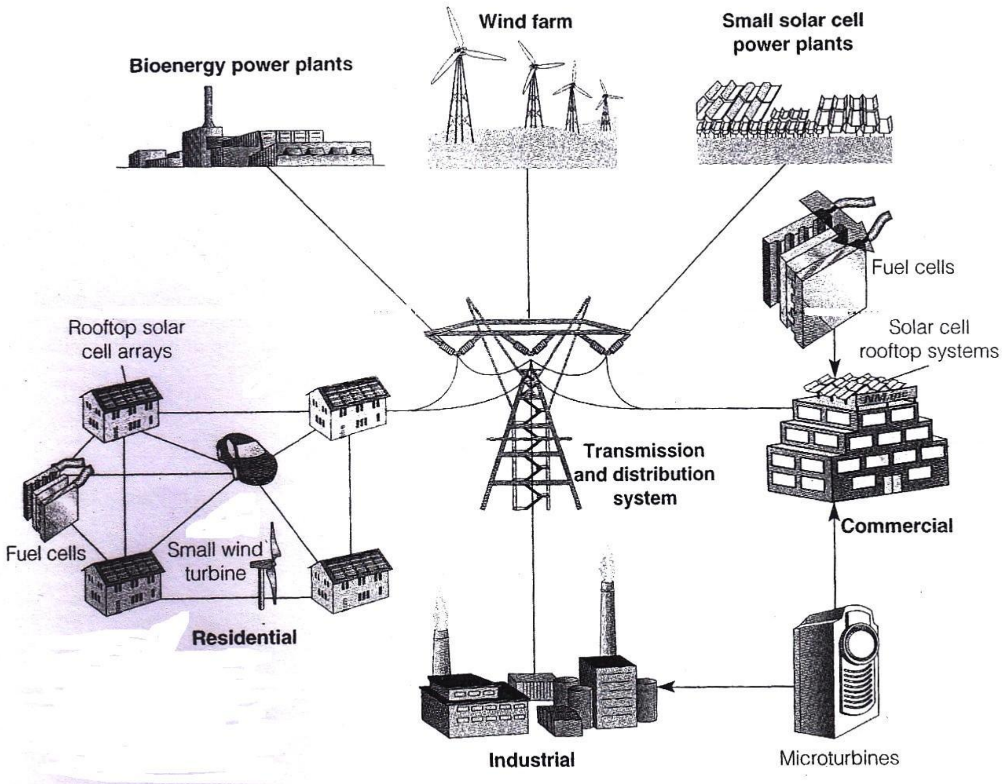


Figure 10.28: Solutions: *decentralized power system* in which electricity is produced by a large number of dispersed, small-scale *micropower systems* (producing 1-10,000 kilowatts of power). Some would produce-power on site and others would feed the power they produce into a conventional electrical distribution system. Over the next few decades, many energy and financial analysts expect a shift to this type of power system

Examples of micropower systems include such energy-efficient systems as natural gas-burning micro-turbines for commercial buildings and residences (5-10,000 kilowatts), wind turbines (1-3,000 kilowatts), Stirling engines (0.1-100 kilowatts), fuel cells (1-10,000 kilowatts), and household solar panels and solar roofs (1-1,000 kilowatts). Figure 3.29 lists some of the advantages of decentralized micropower systems over traditional macropower systems.

Solutions: a sustainable energy strategy

What Are the Best Energy Alternatives? Many scientists and many energy experts who have evaluated energy alternatives have reached three general conclusions:

- There will be a gradual shift from centralized macro power systems (Figure 20-34) to smaller, decentralized micro-power systems (Figures 3.28).

- The best alternatives are a combination of improved energy efficiency and using natural gas as a fuel to make the transition to increased use of a variety of small-scale, decentralized, locally available renewable energy resources and possibly nuclear fusion (if it proves feasible).
- Over the next 50 years, the choice is not between using nonrenewable fossil fuels and various types of renewable energy.

Because of their supplies and low prices, fossil fuels will continue to be used in large quantities. The challenge is to find ways to reduce the harmful environmental impacts of widespread fossil fuel use, with special emphasis on reducing air pollution and emissions of greenhouse gases as less harmful alternatives are phased in.

What Role Does Economics Play in Energy Resource Use? To most analysts the key to making a shift to more sustainable energy resources and societies is not technology but economics and politics. Governments can use three basic economic and political strategies to help stimulate or dampen the short-term and long-term use of a particular energy resource.

One approach is to allow all energy resources to compete in a free market without any government interference. This is rarely politically feasible because of well-entrenched government intervention in the marketplace in the form of subsidies, taxes, and regulations. Furthermore, the free-market approach, with its emphasis on short-term profit, can inhibit development of new energy resources, which can rarely compete economically in their early stages without government support.

A *second* approach is to keep energy prices artificially low to encourage use of selected energy resources. This is done mostly by providing research and development subsidies and tax breaks and enacting regulations that help stimulate the development and use of energy resources receiving such support. For decades, this approach has been used to help stimulate the development and use of fossil fuels and nuclear power in the United States and most other developed countries. This follows the general economic rule that *yon get more of what you reward.* So far, this approach has created an uneven economic playing field that encourages energy waste and rapid depletion of nonrenewable energy resources. It also discourages the development of energy alternatives such as energy efficiency and renewable energy that are getting much lower levels of subsidies and tax breaks than fossil fuels and nuclear power.

A *third* option is to keep energy prices artificially high to discourage use of a resource. Governments can raise the price of an energy resource by withdrawing existing tax breaks and other subsidies, enacting restrictive regulations, or adding taxes on its use. This increases government revenues, encourages improvements in energy efficiency, reduces dependence on imported energy, and decreases use of an energy resource that has a limited future supply.

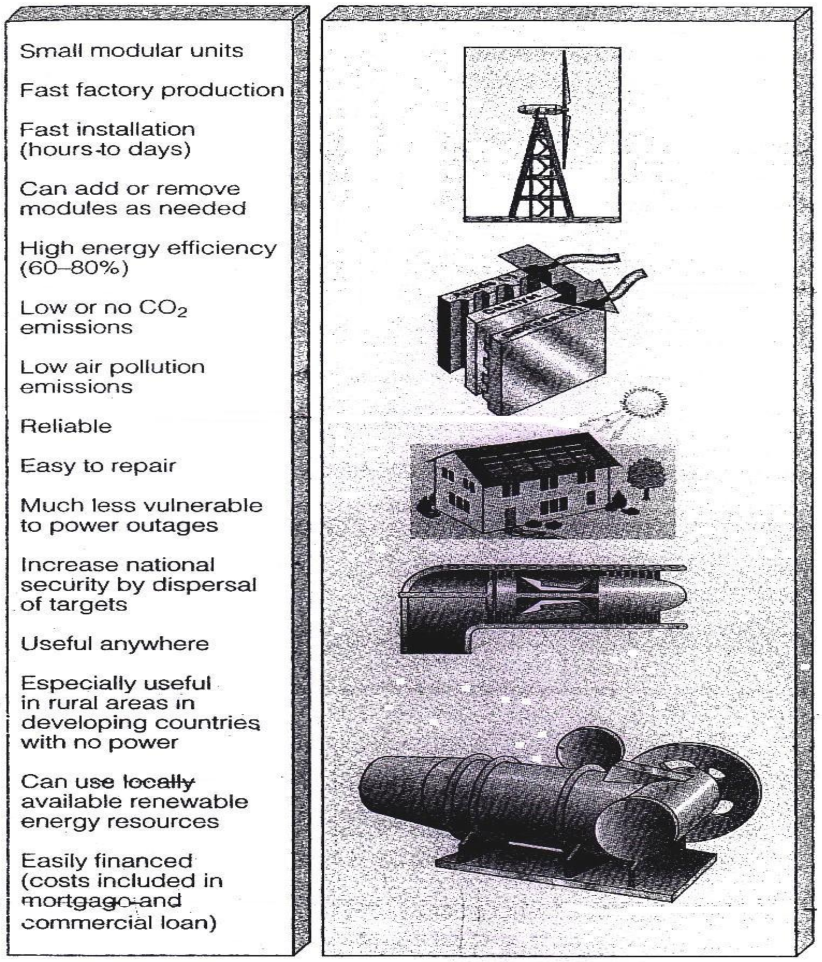


Figure 10.29: Good news: Advantages os micro power systems

Many economists favor *increasing taxes on fossil fuels* as a way to reduce air and water pollution and slow' global warming. The tax revenues would be used to reduce income taxes on wages and profits, improve energy efficiency encourage use of renewable energy resources, and provide energy assistance to the poor and lower middle class. Some economists believe the public might accept these higher taxes if income and payroll taxon wore lowered as gasoline or other fossil fuel taxes were raised.

How Can We Develop a More Sustainable Energy Future? Figure 3.30 lists strategies for making the transition to a more sustainable energy future over the next few decades. Energy experts estimate that implementing policies such as those shown in over the next 20-30 years could save money, create a net gain in jobs, reduce greenhouse gas emissions, and sharply reduce air pollution and water pollution. According to proponents, these policies would also increase national security in two ways. One is reduced dependence on imported oil. The other is decreased dependence on nuclear power and coal plants that are vulnerable to terrorist attacks (Figure 10.29).

Some *great news* is that we have the technology, creativity, and wealth to make the transition to a more sustainable energy future. The *challenging news* is that making this happen depends primarily on *politics*— which depends largely on pressure individuals put on elected officials. See this chapter's website for actions you can take to promote this transition.

Natural Resources: Non Renewable

In 2003 seventeen years after the accident an area of the former Soviet Union about the size of the state of Florida remains highly contaminated with radioactivity. Despite the dangers, between 100,000 and 200,000 people either illegally remained or have returned to live inside this highly radioactive zone.

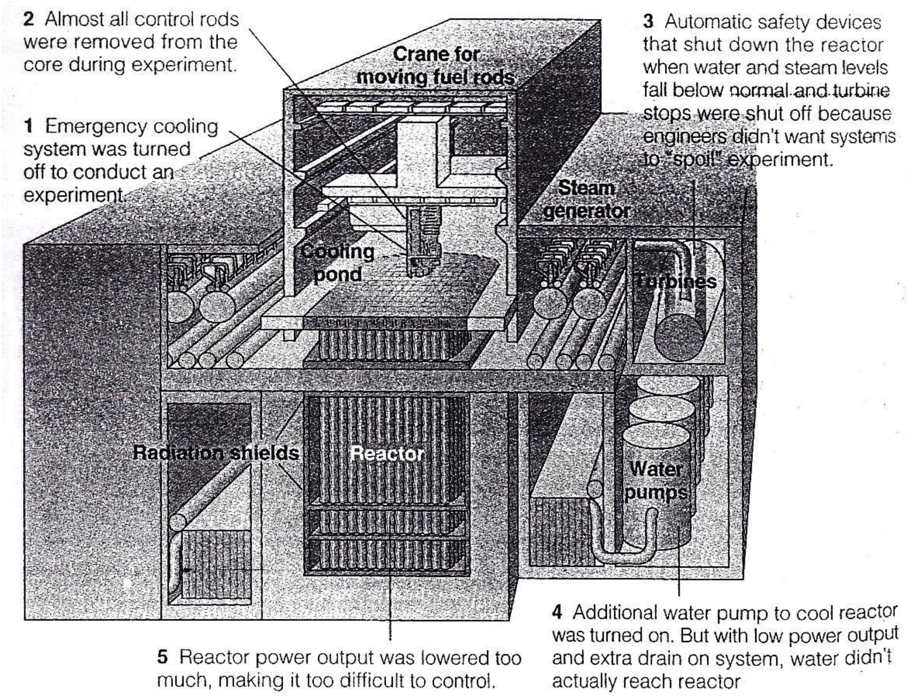


Figure 10.30: Major events leading to Chernobyl nuclear power plant Accident on April 26, 1986 in the Soviat Union

The accident exposed more than half a million people to dangerous levels of radioactivity and has caused several thousand cases of thyroid cancer. The total cost of the accident will reach at least $358 billion. This is many times more than the value of all nuclear electricity ever generated in the former Soviet Union. The environmental refugees evacuated from the Chernobyl region had to leave their possessions behind. They also had to say good-bye to lush green wheat fields and blossoming apple trees, land their families had farmed for generations, cows and goats that would be shot because the grass they ate was radioactive, and their cats and dogs poisoned with radioactivity. They will not be able to return without exposing themselves to potentially harmful doses of ionizing radiation. **Figure 10.30**

Chernobyl taught us that a major nuclear accident anywhere is a nuclear accident everywhere. Typical citizens of advanced industrialized nations each consume as much energy in six months as typical citizens in developing countries consume during their entire life.

Evaluating energy resources

What Types of Energy Do We Use? Some 99% of the energy used to heat the earth and all of our buildings come directly from the sun. Without this direct input of essentially inexhaustible solar energy, the earth's average temperature would be -240°C (—400°F), and life as we know it would not exist. This direct input of solar energy also produces other indirect forms of renewable: solar energy. Examples are wind, falling and flowing water (hydropower), and biomass (solar energy converted to chemical energy stored in chemical bonds of organic compounds in trees and other plants).

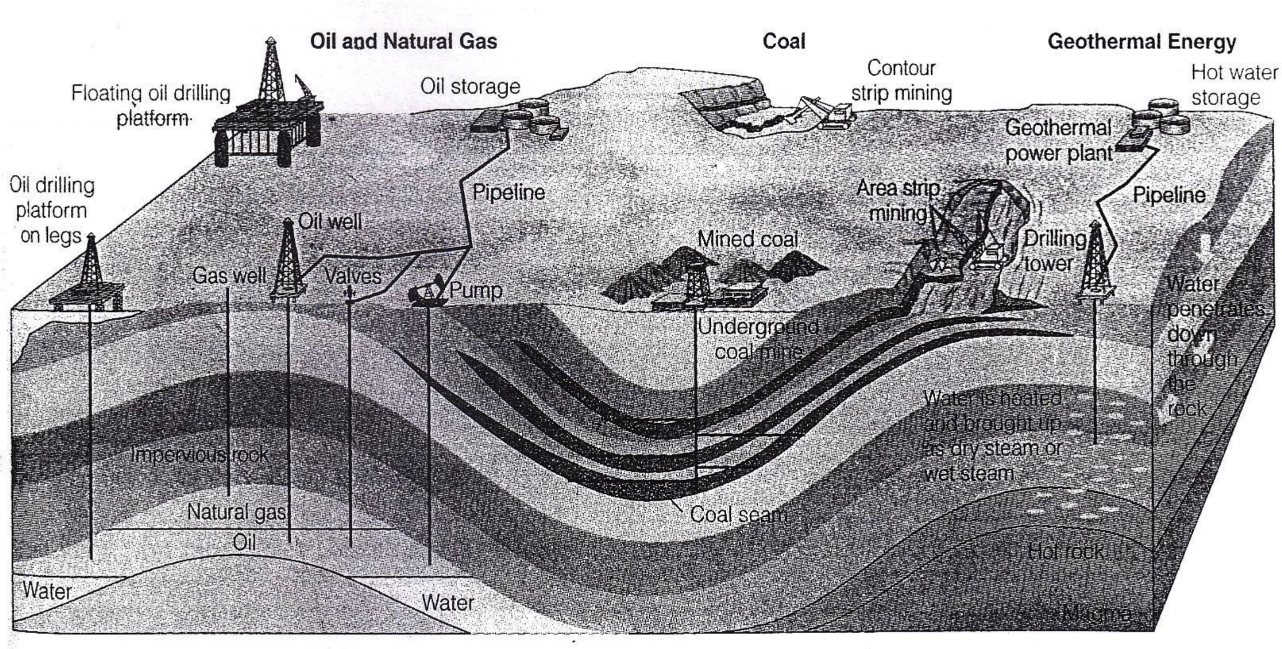


Figure 10.31: ***Natural capital:*** **important nonrenewable energy resources that can be removed from the earth's crust are coat, oil, natural gas, and some forms of geothermal energy. Nonrenewable uranium ore is also extracted from the earth's crust and then processed to increase its concentration of uranium-235, which can be used as a fuel in nuclear reactors to produce electricity.**

Commercial energy sold in the marketplace makes up the remaining 1% of the energy we use to supplement the earth's direct input of solar energy. Most commercial energy comes from extracting and burning *nonrenewable mineral resources* obtained from the earth's crust, primarily carbon-containing fossil fuels (oil, natural gas, and coal; Figure 10.31).

What Types of Energy Does the World Depend On?

Over the past -60, 000 years major cultural changes and technological advances have greatly increased energy use per person. As a result of such advances, about 82% of the commercial energy consumed in the world comes from *nonrenewable* energy resources (76% from fossil fuels and 6% from nuclear power; Figure 10.32, left).

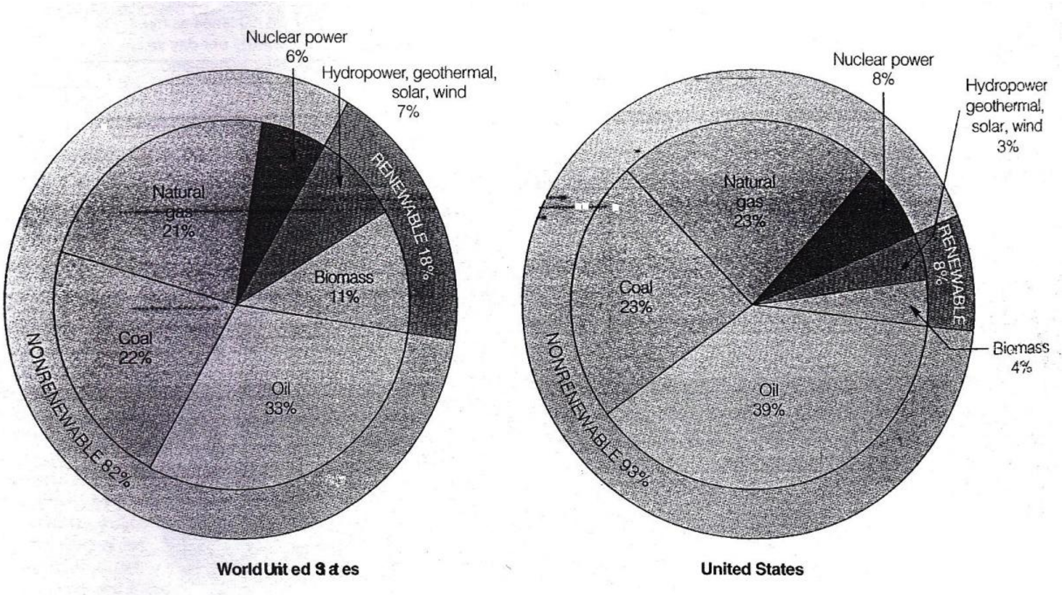
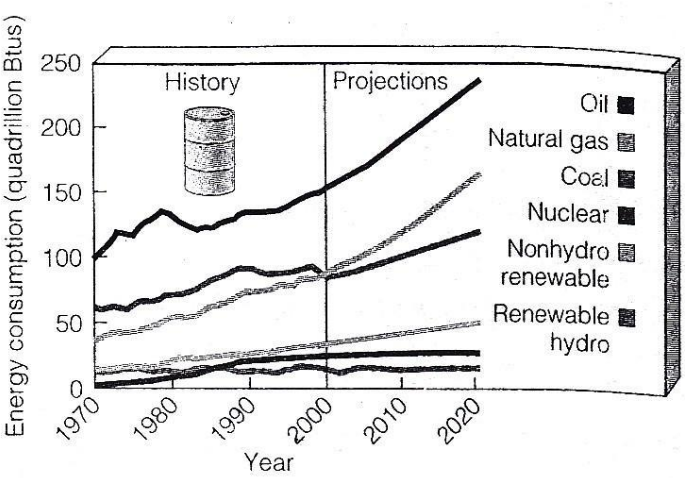


Figure 10.32: Commercial energy use by source for the world (left) and the United States (right) in 2001. Commercial energy amounts to only 1 % of the energy used in the world; the other 99% is direct solar energy received from the sun and is not sold in the marketplace. (Data from U.S. Department of Energy, British Petroleum, and WorldWatch Institute)

Figure 3.33 shows the world's increase in consumption of energy by fuel type between 1970 and 2000, with projections to 2020. In developing countries, the main source of energy for heating and cooking for roughly half the world's population is renewable energy from *biomass* (mostly fuel wood and charcoal made from fuel wood)—as long as wood supplies are not harvested faster than they are replenished. Some *"bail news* is that many of the world's people in developing countries face a *fuel wood shortage* that is expected to get worse because of unsustainable harvesting of fuel wood. Many of these people (especially women and children) die prematurely from breathing particles emitted by burning wood indoors in open fires and poorly designed primitive stoves.

What Types of Energy Does the United States Depend On? The United States is the world's largest energy user. With only 4.6% of the population, in 2002 it used 26% of the world's commercial energy. This is more energy than the combined total used by the next four largest energy-consuming countries— China, Russia, Japan, and Germany. In contrast, India, with 16% of the world's people, uses about 3% of the world's commercial energy. **Fgure10.33** About 93% of the commercial energy used in the United States comes from *nonrenewable* energy resources (85% from fossil fuels and 8% from nuclear power; Figure 10.32, right).



Fgure10.33: Global energy consumption by fuel type, 1970-2000, with projections to 2020, (A Btu is a British thermal unit, a standard measttre-of'heatforvatae! comparison of various fuels.) (Data from U.S. Department of Energy)

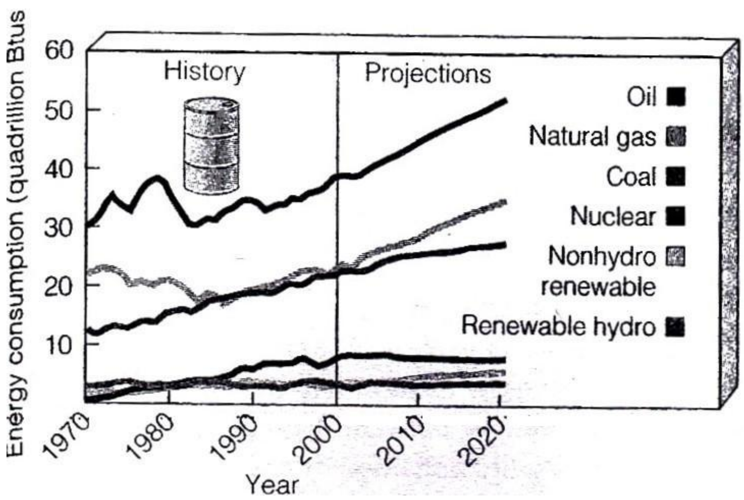


Figure 10.34: Energy consumption by fuel in the United States, 1997-2000, with projections to 2020

Figure 10.34 shows- energy consumption by fuel in the United States from 1970 to 2000, with projections to 2020. Note that the main-projected trends between 2000 and 2020 are increased use of oil and natural gas and a leveling off of coal use. An important environmental, economic, and political issue is what energy resources the United States might be using by 2050 and 2100. Figure 19-7 shows shifts in use of various sources of energy in the United States since 1800 and one scenario showing projected changes to a hydrogen-solar energy age by 2100.

According to the U.S. Department of Energy and the Environmental Protection Agency, burning fossil I fuels causes more than 80% of U.S. air pollution and 80% of U.S. carbon dioxide emissions. Many energy experts contend that the need to use cleaner and less climate-disrupting (noncarbon) energy resources not the depletion of fossil fuels—is the driving force behind the projected global transition to a solar-hydrogen energy age in the United States and other parts of the world before the end of this century (Figure 10.35).

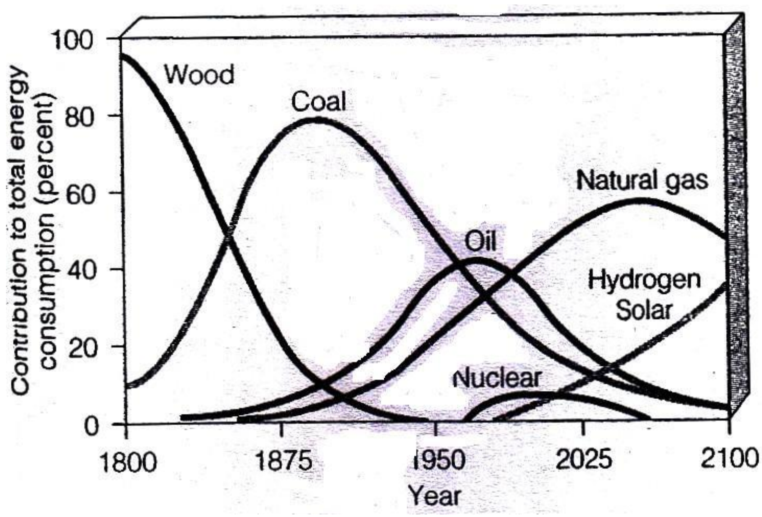


Figure 10.35: Shifts in the use of commercial energy resources in the unites states since 1800, with projected changes to 2100. Shifts from wood to coal and then from coal to oil and natural gas have each taken about 50 years. The projected shift to hydrogen solar energy in 2100 is only one of many possible scenarios depending on a variety of assumptions

How Can We Decide Which Energy Resources to Use? There is intense scientific, economic, and political controversy over which energy resources we should rely on now and in the future. As discussed in this chapter and the one that follows, each energy resource has advantages and disadvantages that must be carefully evaluated. Energy policies need to be developed with the future in mind because experience shows that it usually takes at least 50 years and huge-investments to phase in new energy alternatives, to the point where they provide 10-20%

of total energy use. Making projections such as those in Figure 3.35 involves trying to answer the following questions for *each* energy alternative:

- How much of the energy source will be available in the near future (the next 15-25 years) and the long term (the next 25-50 years).
- What is this source's net energy yield?
- How much will it cost to develop, phase in, and use this energy resource?
- What government research and development subsidies and tax breaks will be provided for each energy resource to spur its development?
- How will dependence on each energy resource affect national and global economic and military security?
- How vulnerable is each source of energy to terrorism?
- How will extracting, transporting, and using the energy resource affect the environment, human health, and the earth's climate? Should these harmful costs be included in the market prices of each energy resource through a combination of taxes and phasing out environmentally harmful subsidies (full-cost pricing)

What Is Net Energy? The Only Energy That Really Counts It takes energy to get energy. For example, before oil is useful to us it must be found, pumped up from beneath the ground or ocean floor, transferred to a refinery and converted to useful fuels (such as gasoline, diesel fuel, and heating oil), transported to users, and burned in furnaces and cars. Each of these steps uses high-quality energy. The second law of thermodynamics tells us that some of the high-quality energy (Figure 3-10) we use in each step is wasted and degraded to lower-quality energy.

The usable amount of *high-quality energy* available from a given quantity of an energy resource is its net energy. It is the total amount of energy available from an energy resource minus the energy needed to find, extract, process, and get that energy to consumers. It is calculated by estimating the total energy available from the resource over its lifetime minus the amount of energy *used* (the first law of thermodynamics), *automatically wasted* (the second law of thermodynamics), and *unnecessarily wasted* in finding, processing, concentrating, and transporting the useful energy to users.

Net energy is like your net spendable income (your wages minus taxes and job-related expenses). For example, suppose that for every 10 units of energy in oil in the ground we have to use and waste 8 units of energy to find, extract, process, and transport the oil to users. Then we have, only 2 units of *useful energy* avail able from every10 units of energy in the oil.

We can express net energy as the ratio of useful energy produced to the useful energy used to produce it. In the example just given, the *net energy ratio* would be 10/8, or 1.25. The higher the ratio, the greater the net energy. When the ratio is less than 1, there is a net energy loss. Currently oil has a high net energy ratio because much of it comes from large, accessible, and cheap-to-extract deposits such as those in the Middle East. When those sources are depleted, the net energy ratio of oil will decline and prices will rise. Then more money and high-quality fossil fuel energy will be needed to find process, and deliver new oil from less accessible sites They include deposits that are small and widely dispersed, buried deep in the earth's crust, and located in remote areas or further- and further offshore.

Conventiona1 nuclear energy has a tow net energy ratio because large amounts of energy are needed to extract and process uranium ore, convert it into a usable nuclear fuel, build and operate nuclear power plants, dismantle the highly radioactive plants after their 15-60 years of useful life, and store the resulting highly radioactive wastes safely for 10,000-240,000 years depending on the types of radioisotopes they contain. Each of these steps in what is called the *nuclear fuel cycle* uses energy and costs money.

Oil

What Is Crude Oil, and How Is It Extracted and processed? Petroleum, or crude oil (oil as it comes out of the ground), is a thick liquid consisting of hundreds of combustible hydrocarbons along with small amounts of sulfur, oxygen, and nitrogen impurities. This fossil fuel was produced by the decomposition of dead organic matter from plants (primarily plankton) and animals that were buried under lake and ocean sediments 2-140 million years ago. The resulting high temperatures and pressures over millions of years converted this dead organic matter to oil as part of the carbon cycle.

Deposits of crude oil and -natural gas- often are trapped together under a dome deep within the earth's crust on land or under the seafloor (Figure 10.36). The crude oil is dispersed in pores and cracks in underground rock formations, somewhat like water saturating a sponge. To extract the oil, a well is drilled into the deposit. Then oil that is drawn by gravity out of the rock pores and into the bottom of the well is pumped to the surface.

On average, producers get only about 35% of the oil out of an oil deposit. They then abandon the-well because the remaining *heavy crude oil* is too difficult or expensive to recover. As oil prices rise, it can become economical to remove about 10-25% of this remaining- heavy oil by flushing the well with steam and water. But the net energy yield for such recovered oil is lower because it takes the energy in one-third of a barrel of refined oil to retrieve each barrel of heavy crude oil.

Drilling for oil causes only moderate damage to the earth's land because the wells occupy fairly little land area. However, oil drilling always involves some oil spills on land and in aquatic systems. In addition, harmful environmental, effects are associated with the extraction, processing, and use of any nonrenewable resource from the earths crust.

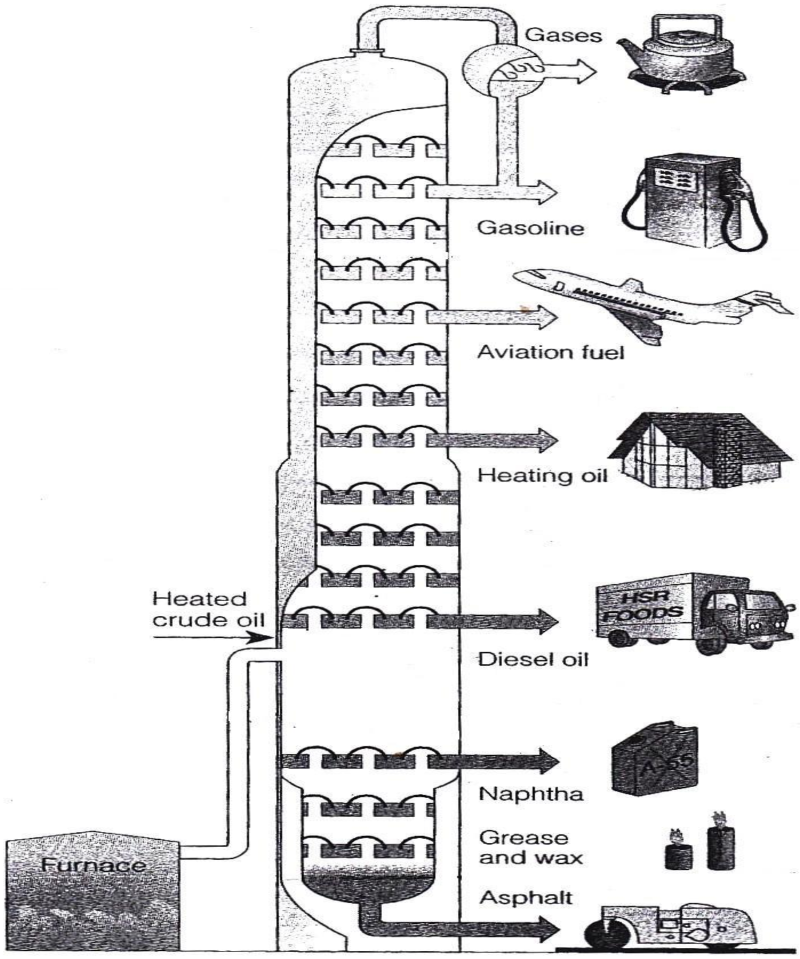


Figure 10.36: Refining crude oil. Based on their boiling points, components are removed at various levels in a giant distillation column. The most volatile components with the lowest boiling points are removed at the top of the column

According to oil producers, several improved extraction technologies can increase oil production without serious damage to environmentally sensitive areas. One is new equipment that allows oil and natural gas producers to drill deeper on land and the ocean bottom. In addition, oil producers can now use one drilling rig (derrick) to drill several gas or oil pockets at the same time. Another new technology allows oil fir gas extraction from distances as far away as 8 kilometers (5 miles) by drilling at angles of 90 degrees or more (slant drilling).

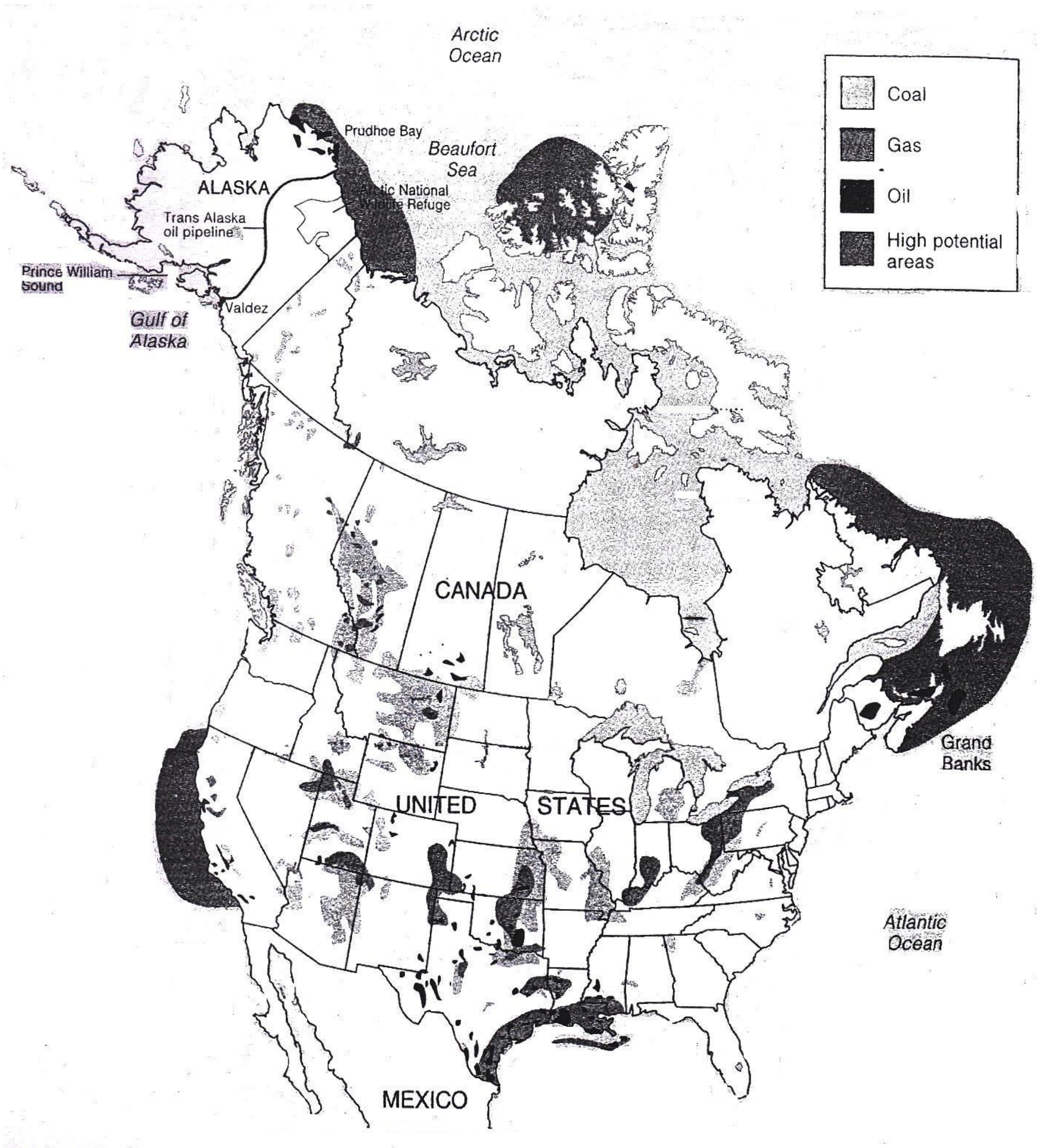


Figure 10.37: ***Natural capital:*** **locations of the major known deposits of oil, natural gas, and coal in North America and offshore areas where more crude oil and natural gas might be found. Geologists do not expect to find very much new oil and natural gas in North America. (Data from Council on Environmental Quality and U.S. Geological Survey)**

After it is extracted, crude oil is transported to a refinery by pipeline, truck, or ship (oil tanker). There it is heated and distilled in gigantic columns to separate it into components with different boiling points (Figure 10.37). Some products of oil distillation, called Petrochemicals, are used as raw materials in manufacturing industrial organic chemicals, pesticides, plastics, synthetic fibers, paints, medicines, and many other products.

Who Has the World's Oil Supplies? Oil *reserves* are identified deposits from which oil can be extracted profitably at current prices with current technology. The 11 countries that make up the Organization of Petroleum Exporting Countries (OPEC) have 78% of the world's estimated crude oil reserves. This explains why OPEC is expected to have long-term control over the supplies and prices of the world's conventional oil. Saudi Arabia, with 25%, has by far the largest proportion of the world's crude oil reserves, followed by Iraq (11%), the United Arab Emirates (9.3%), Kuwait (9.2%), and Iran (8.5%). Most of the world's remaining global crude oil reserves is found in Venezuela (7.4%), Africa (7.3%), the former Soviet Union (6.2%), Asia (4.2%, with 2% in China), the United States (2.9%), Mexico (2.6%), and Western Europe (1.8%).

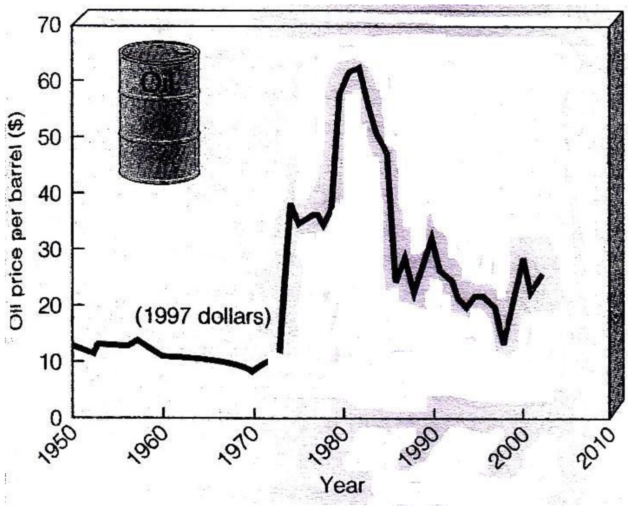


Figure 10.38: Inflation adjustment price of oil, 1950-2002. When adjusted for inflation, oil costs about the same as it did in 1975. Although low oil prices have stimulated economic growth, they have discouraged improvements in energy efficiency and increased use of renewable energy resources

Case Study: How Much Oil Does the United States Have?

Figure10.38. shows the locations of the major known deposits of fossil fuels (oil, natural gas and coal) in the United States and Canada and ocean areas where more crude oil and natural gas might be found in 2001, about 25% of U.S. domestic oil production came from offshore drilling (mostly off the coasts ofTexas and Louisiana) and 17% from Alaska's North Slope.

The United States has only 2.9% of the world's oil reserves. However, it uses about 26% of the crude oil extracted worldwide each year (68% of it for transportation), mostly because oil is an abundant and convenient fuel to use and is cheap (Figure 3.38). Despite an upsurge in exploration and test drilling, U.S. oil extraction has declined since 1985, and most geologists do not expect a significant increase in domestic supplies (Figure10.39).

In 2002, the United States imported about 55% of the oil it used (up from 36% in 1973 during the OPEC oil embargo). Reasons for this high dependence on imported oil are declining domestic oil reserves, higher production costs for domestic oil than for most sources of imported oil, and increased oil use. In 2001, the U.S. bill for oil imports was about $100 billion—an average of $11 million per hour. According to the Department of Energy (DOE), the United States could be importing at least 61% of the oil it uses by 2010 and 64% by 2020 (Figure 10.39).

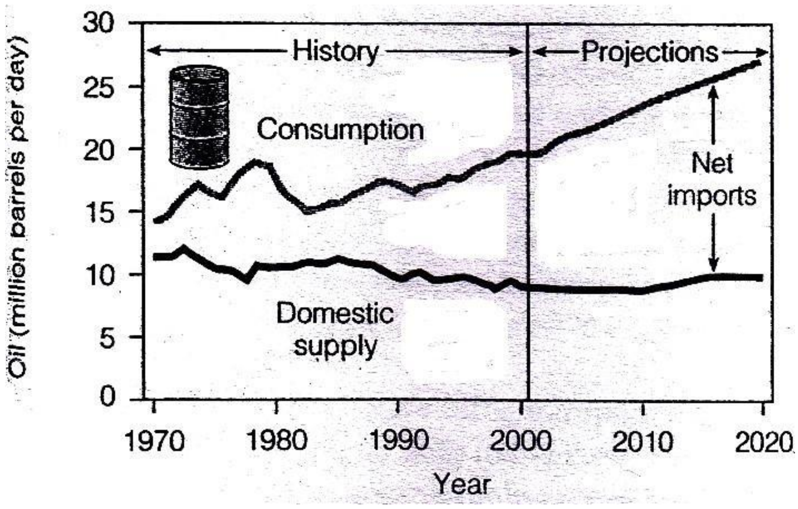


Figure 10.39: U.S. Petroleum supply, consumption, and imports, 1970-2002, with projections to 2020

How Long Will Oil Supplies Last? Production of the world's estimated oil reserves is expected to peak between 2010 and 2030 (Figure 3.40, top) and production of estimated U.S. reserves peaked in 1975 (Figure 3.38 and Figure 3.40, bottom)**.** Identified global reserves of oil should last about 53 years at the current usage rate, and 42 years if usage increases exponentially by about 2% per year. Undiscovered oil that is thought to exist might add another 20-40 years to global oil supplies, probably at higher prices. Thus known and projected supplies of oil are expected to be 80% depleted -within 42-93 years depending on the annual rate of use.

U.S. oil reserves should last about 15-24 years (Figure 10.40, bottom) at current consumption rates arid 10-15 years if consumption increases as projected. However, potential reserves might yield an additional 24 years of production. Thus U.S. oil supplies are protected to be 80% depleted within 10-48 years, depending on the annual rate of use.

Some analysts contend that rising oil prices (when oil consumption exceeds oil production) will stimulate exploration and lead to discovery of new reserves to meet future demand through the next century or longer. Other analysts argue that such projections ignore the consequences of the high (1-5% per year) exponential growth in oil consumption.

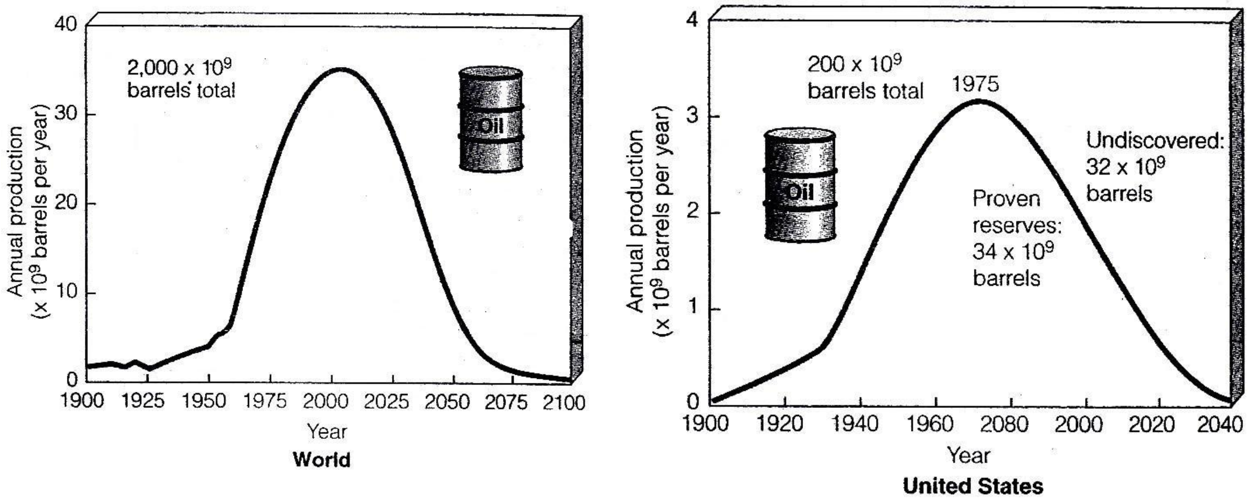


Figure 10.40: Petroleum production curves for the world (left) and the United States (right)

For example, suppose that we continue to use oil at the current rate with no increase in oil consumption (an unlikely assumption). Even under this conservative estimate.

- Saudi Arabia, with the world's largest crude oil reserves, could supply world oil needs for about 10 years.
- The estimated reserves under Alaska's North Slope (the largest ever found in North America) would meet current world demand for only 6 months or U.S demand for 3 years.
- The estimated reserves in Alaska's Arctic National Wildlife Refuge would meet the world's current oil demand for only 1-5 months or U.S. oil demand for 7-24 months.
- Estimated oil reserves on other federal lands on Alaska's North Slope would meet the current world oil demand for 10 days to 2 months or U.S. demand for 2-11 months.

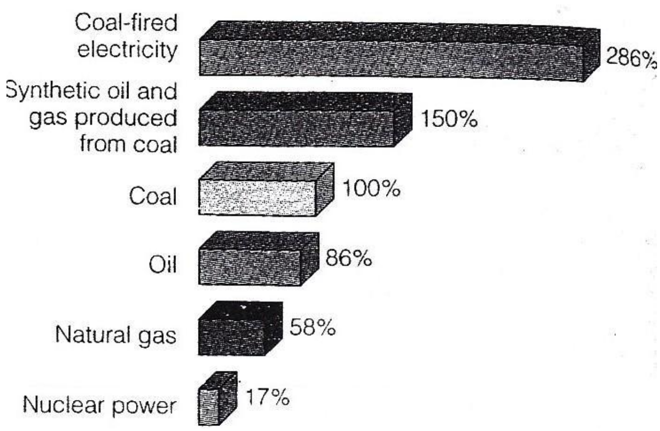


Figure 10.41: $C0_2$ emissions per unit of energy produced by various fuels, expressed as percentages of emissions produced by burning coal directly

In short, to keep using conventional oil at the *current rate*, we must discover global oil reserves equivalent to a new Saudi Arabian supply *every 10 years*. According to the Bush administration, the United States can reduce its dependence on imported oil and have more control over global oil prices by increasing domestic oil supplies. Most analysts consider this unrealistic because the United States has only 2.9% of the world's oil reserves and uses 26% of the world's annual oil production. **Figure 10.41**The country also produces most of its dwindling supply of oil at a high cost of $5-7.50 per barrel compared to production costs of less than $1.50 per barrel in Persian Gulf countries. Thus opening all of the U.S. coastal water, forests, and wild places to drilling would hardly put a dent in world oil prices or meet much of the growing U.S. demand for oil (Figures 10.34 and 10.38). Burning any carbon-containing fossil fuel releases $C0_2$ into the atmosphere and thus can promote global warming. Figure 3.41 compares the relative amounts of $C0_2$ emitted per unit of energy by the major fossil fuels and. nuclear power. Currently, burning oil mostly as gasoline and diesel fuel for transportation accounts for 43% of global $C0_2$ emissions.

Case Study: Should Oil and Gas Development Be Allowed in the Arctic National Wildlife Refuge?

The Arctic National Wildlife Refuge (ANVVR) on Alaska's North Slope (Figure 10.37) contains more than one-fifth of all land in the U.S. National Wildlife Refuge-System, and has been called the crown jewel, of the system. The refuges coastal plain, its most biologically productive part, is the only stretch of Alaska's arctic coastline not open to oil and gas development.

The Alaskan National Interest Lands Conservation Act of 1980 requires authorization from Congress before drilling or other development can take place on this coastal plain. For years, U.S. oil companies have been lobbying Congress to grant them permission to carry out exploratory drilling in the coastal plain because they believe this area might contain oil and natural gas deposits. Environmentalists and conservationists strongly oppose drilling in this area. Figure10.42 summarizes the opposing positions in this intense environmental controversy.

According to drilling opponents, improving motor vehicle fuel efficiency is a much faster, cheaper, cleaner, and more secure way to increase future oil supplies. For example, requiring new SUVs and light trucks used in-the United States to have the same average fuel efficiency as new cars would save more oil in 10 years than would ever be produced from the ANWR.

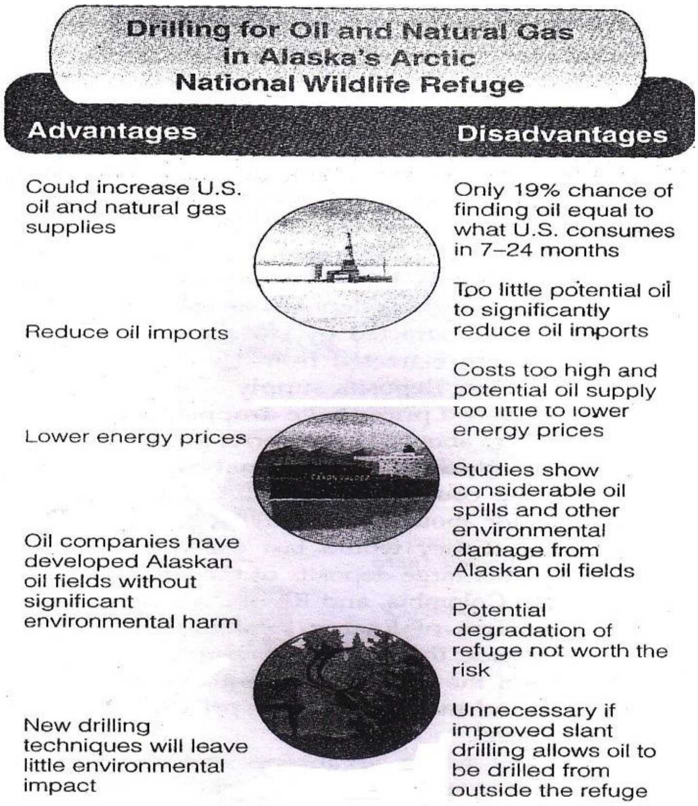


Figure 10.42: Advantages and Disadvantages of drilling for oil and natural gas in Alaska's Arctic National Wildlife Refuge (ANWR)

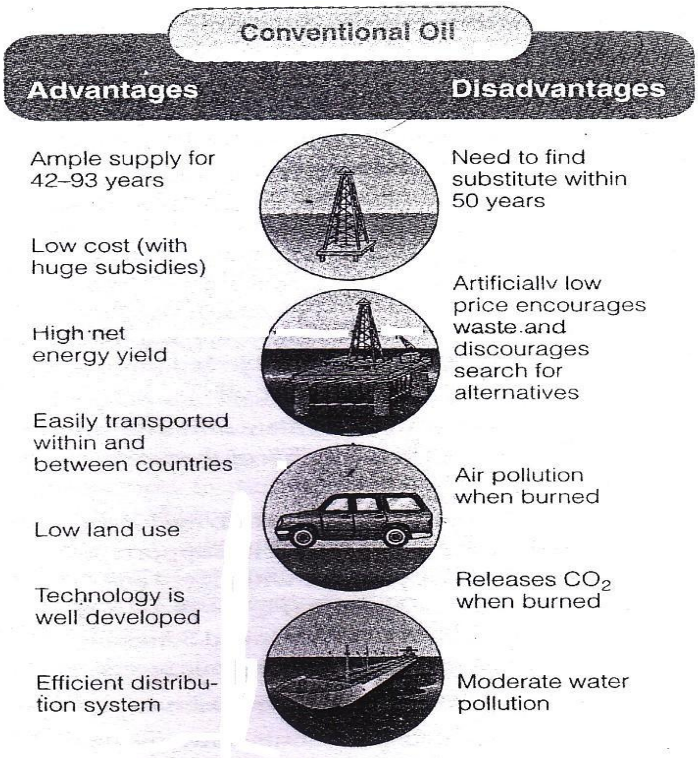


Figure 10.43: Trade offs: Advantages and Disadvantages of using conventional oil as an energy resource

What Is the Future of Conventional Oil? A Brief History of the Age **of Oil** Figure 10.43 lists the advantages and disadvantages of using conventional crude oil as an energy resource. We are heavily dependent on conventional oil today because it has a high energy content and net energy yield, low cost (as long as supplies exceed demand), and is easy to transport within and between countries. In 1859, the world's first commercial oil well was drilled in Titusville, Pennsylvania. This was the beginning of the *Age of Oil,* which now supplies most of the world's energy (Figure 10.33, left). We are not running out of oil, but many energy experts expect that by 2059—some 200 years after oil was discovered—we will probably begin shifting to increased dependence on natural gas and possibly hydrogen by 2100 (Figure 10.35). Here are some milestones in the Age of Oil:

- 1905: Oil supplies 10% of U.S. energy.
- 1925: United States produces 71% of the world's oil.
- 1930: Because of an oil glut, oil sells for 10c a barrel.
- 1953: U.S. oil companies account for about half of the world's oil production and the United States is the world's leading oil exporter.
- 1955: United States has 20% of the world's estimated oil reserves.
- 1960: OPEC formed so developing countries, with most of the world's known oil and projected oil reserves, can get a higher price for their oil.
- 1973: United States uses 30% of the world's oil, imports 36% of this oil, and has only 5% of the worlds proven oil reserves.
- 1973-1974: OPEC reduces oil imports to the West and bans oil exports to the U.S. because of its support for Israel in the 18-day Yom Kippur War with Egypt and Syria. World oil prices rise sharply (Figure 3.38) and lead to double-digit inflation in the United States and many other countries and a global economic recession.
- 1975: Production of estimated U.S. oil reserves peaks.
- 1979: Iran's Islamic Revolution shuts down most of Iran's oil production and reduces world oil production.
- 1981: Iran-Iraq war pushes global oil prices to a historic high (Figure10.38).
- 1983: Facing an oil glut, OPEC cuts its oil prices.
- 1985: U.S. domestic oil production begins to decline and is not expected to increase enough to affect the global price of oil or to reduce U.S. dependence on oil imports (Figure 10.39).
- August 1990-June 1991: United States and its allies fight the Persian Gulf War to oust

Iraqi invaders of Kuwait and to protect Western access to Saudi Arabian and Kuwaiti oil supplies.

- 2002: OPEC has 67% of world oil reserves and produces 40% of the world's oil. U.S. has only 2.9% of oil reserves, uses 26% of the world's oil production, and imports 55% of its oil.
- 2010: U.S. could be importing at least 61% of the oil it uses as consumption continues to exceed production (Figure 10.39).
- 2010-2030: Production of oil from the world's estimated oil reserves is expected to peak (Figure 3.40, top). Oil prices expected to increase gradually as the demand for oil increasingly exceeds the supply—unless the world decreases demand by wasting less energy and shifting to other sources of energy.
- 2010-2048: Domestic U.S. oil reserves projected to be 80% depleted.
- 2042-2083: Gradual decline in dependence on oil.

In 1999, Mike Bowling, CEO of ARCO Oil, said, "We are embarked on the beginning of the last days "of the Age of Oil." He went on to discuss the need for the world to shift from a carbon-based to a hydrogen-based energy economy during this century (Figure 10.35).

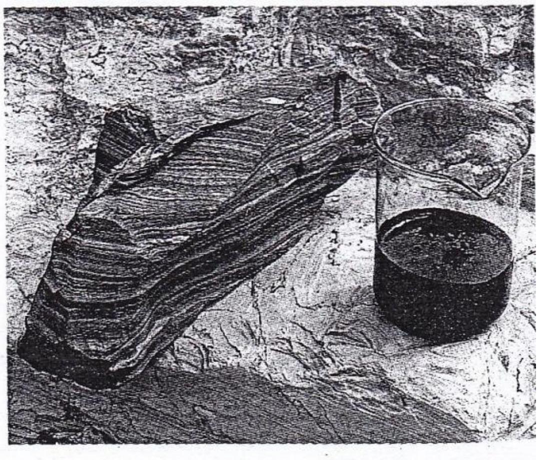


Figure 10.44: Oil shale (left) and the Shale oil (right) extracted from it. Big U.S. oil shale projects have been canceled because of excessive cost

How Useful Are Heavy Oils from Oil Shale and Tar Sands? *Oil shale* is a fine-grained sedimentary rock (Figure 10.44, left) containing a solid combustible organic material called *kerogen.* This material-can be distilled from oil shale by heating it in a large container to yield *shale oil* (Figure 10.44, right). Before the thick shale oil can be sent by pipeline to a refiner)', it must be heated to increase its flow rate and processed to remove sulfur, nitrogen, and other impurities.

Some *good news* is that estimated potential global supplies of shale oil are about 240 times larger than estimated global supplies of conventional oil. The *bad news* is that most deposits of oil shale are of such a low grade that with current oil prices and technology it takes more energy and money to mine and convert the kerogen to crude oil than the resulting fuel is worth. However, as oil prices rise it may become economically feasible to exploit some reserves of oil shale.

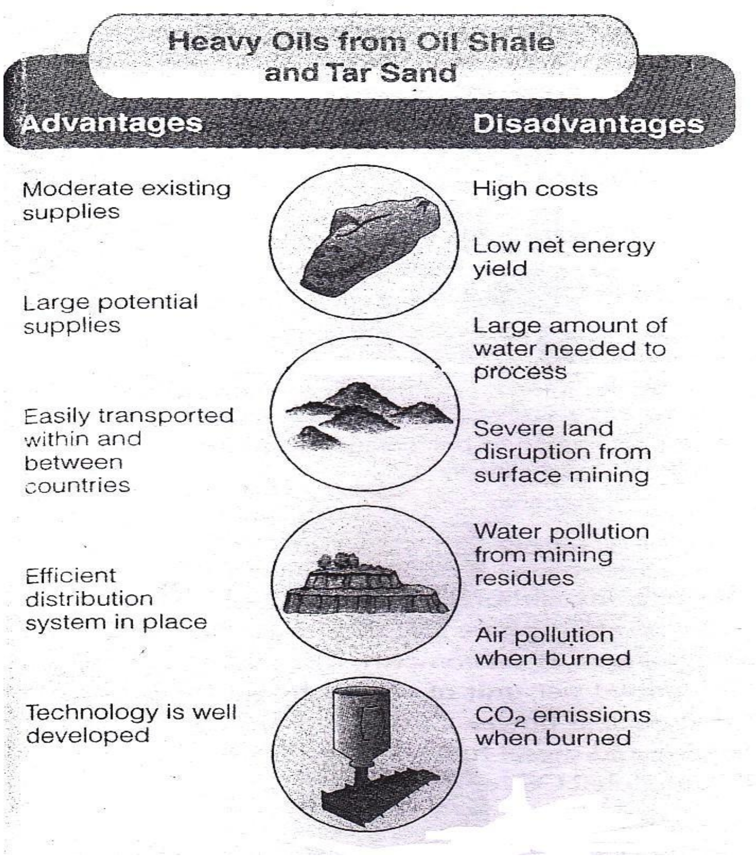


Figure 10.45: Advantages and Disadvantages of using heavy oils from oil shale and tar sand as energy resource

Tar sand (or oil sand) is a mixture of clay, sand water, and a combustible organic material called *bitumen* (a thick and heavy oil with a high sulfur content). Most deposits are too deep underground to be mined at a profit, but some deposits are close enough to the earth's surface to be removed by surface mining. The bitumen is removed, purified, and chemically upgraded into a synthetic crude oil suitable for refining.

The world's largest known deposits of tar sands the Athabasci Tar Sands, lie in northeastern Alberta-Canada. About 10% of these deposits lie close enough to the surface to be extracted by surface mining. In Canada, oil has been extracted from tar sands since 1978.

Currently, these deposits supply about 21% of Canada's oil needs and prices have dropped from $28 per barrel in 1978 to about $11 per barrel in 2001—less than half the current cost of conventional oil.

These deposits could supply all of Canada's projected oil needs for about 33 years at its current consumption rate, but they would last the world only about 2 years. Other large deposits of tar sands are in Utah, Venezuela, Colombia, and Russia. According to the U.S. Department of Energy, exploitation of tar sands could 'increase the global oil reserves by 50% within 25 years if the price of conventional oil rises above $30 per barrel and fivefold if the price of oil rises above $40 per barrel.

Figure 10.45 lists the advantages and disadvantages of using heavy oil from oil shale and tar sand as energy resources. Because of low net energy yields and high development and processing costs, neither of these resources is expected to provide much of the world's energy in the near future. However, as oil prices rise it may become economically feasible to exploit these two sources of heavy oil unless supplies of natural gas and other energy resources cost less to-develop and produce fewer harmful environmental effects.

Natural Gas

What Is Natural Gas? In its underground gaseous state, natural gas is a mixture of 50-90% by volume of methane (CH_4), the simplest hydrocarbon. It also contains smaller amounts of heavier gaseous hydrocarbons such as ethane (C_2H_6), propane (C_3H_8), and butane (C_4H_{10}), and small amounts of highly toxic hydrogen sulfide (H_2S), a by-product of naturally occurring sulfur in the earth. *Conventional natural gas* usually lies above most reservoirs of crude oil (Figure 3.31). Like oil, the natural gas was formed from fossil deposits of plants (mostly phytoplankton) and animals buried on the seafloor for millions of years and subjected to high temperatures and pressures.

Unconventional natural gas is found by itself in other underground sources. One such source is *methane hydrate*, which is composed of small bubbles of natural gas trapped in ice crystals deep under the arctic permafrost and beneath deep-ocean sediments. So far it costs too much to get natural gas from such unconventional sources, but the extraction technology is being developed rapidly.

When a natural gas field is tapped, propane and butane gases are liquefied and removed as liquefied petroleum gas (LPG). LPG is stored in pressurized tanks for use mostly in rural areas that are not served by natural gas pipelines. The rest of the gas (mostly methane) is dried to remove water vapor. Then it is cleansed of poisonous hydrogen sulfide and other impurities and pumped into pressurized pipelines for distribution. At a very low temperature of -184°C (-

300°F), natural gas can be converted to liquefied natural gas (LNG). This highly flammable liquid can then be shipped to other countries in refrigerated tanker ships.

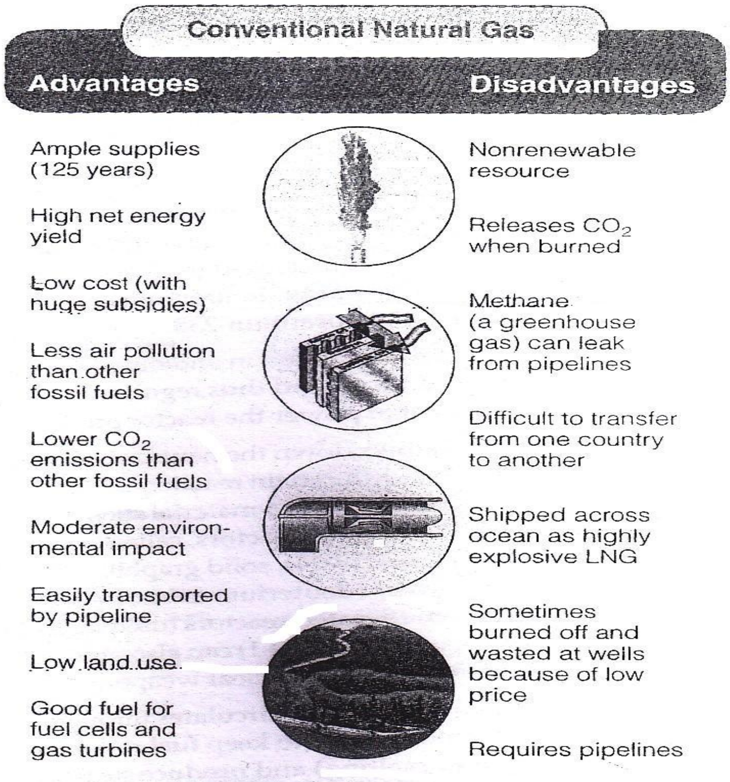


Figure 10.46: Advantages and Disadvantages of using conventional natural gas as an energy resource

Who Has the World's Natural Gas Supplies?

Russia has about 31% of the world's natural gas reserves. Other countries with large known natural gas reserves are Iran (15%), Qatar (9%), Saudi Arabia (4%), the United Arab Emirates (4%) the United States (3%), Algeria (3%), and Venezuela (3%). Geologists expect to find more natural gas, especially in unexplored developing countries. Most U.S. natural gas reserves are located in the same places as crude oil (Figures 10.31 and 10.37).

How Long Will Natural Gas Supplies Last?

The long-term outlook for natural gas supplies is much better .than for oil. At the current consumption rate, known reserves and undiscovered, potential reserves of conventional natural gas in the world are expected to last 125 years and those in the United States for 65-80 years. Geologists estimate that conventional supplies of natural gas, plus unconventional supplies available at higher prices, will last at least 200 years at the current consumption rate and 80 years if usage rates rise 2% per year. Thus global supplies of conventional and unconventional natural gas should last 205-325 years, depending on how rapidly natural gas is used.

What Is the Future of Natural Gas? Figure 10.46 lists the advantages and disadvantages of natural gas as an energy resource. Energy expert's project greatly increased global use of natural gas during this century (Figure10.33) because of its abundant supply, low production costs, and lower pollution and $C0_2$ per unit of energy than other fossil fuels (Figure 10.41).

In combined-cycle natural gas systems, natural gas is burned in combustion turbines, which are essentially giant jet engines bolted to the ground. This system can produce electricity more efficiently than burning coal or oil or using nuclear power. It can also provide backup power for solar energy and wind power systems. In addition, these turbines produce much less $C0_2$ (Figure 10.41) and smog-causing nitrogen oxides per unit of energy than coal-burning power plants. Smaller combined-cycle natural gas units being developed could supply the heat and electricity needs of an apartment or office building.

In 2002, about 380,000 of the world's motor vehicles ran on liquefied or compressed natural gas. In 2002, Honda announced it would begin selling a CivicGX fueled by natural gas. The company has also teamed up with Toronto-based Fuel Maker to mass-market a system that connects to a home's natural gas supply line and allows owners to fuel natural gas vehicles at home. Because of its advantages over oil, coal, and nu clear energy, some analysts see natural gas as the best fuel to help make the transition to improved energy efficiency and greater use of solar energy and hydrogen over the next 50-100 years (Figure 10.35).

What Is the Future of Natural Gas in the United States? In 2001, natural gas was burned to provide 53% of the heat in U.S. homes and 16% of the country's electricity. By 2020, the DOE projects that natural gas will be burned to produce 32% of the country's electricity. However, this will require considerable expansion of the country's natural gas pipeline distribution system. A major problem is that U.S. production of natural gas has been declining for a long time, and experts do not believe this situation will be reversed. More natural gas could be obtained from Canada and Alaska's North Slope. But the pipeline for bringing this gas to the lower 48 states—assuming that it is ever built will take 7-10 years to complete. More liquefied natural gas could be imported by ship. But this requires cooling the gas to -184°C (-300°F), shipping it in special tankers, and building special LNG receiving terminals.

Coal

What Is Coal, and How Is It Extracted and Processed? Coal is a solid fossil fuel formed in several stages as buried remains of land plants that lived 300-400 million years ago were subjected to intense heat and pressure over many millions of years (Figure 10.47). Coal contains small amounts of sulfur, released into the atmosphere as $S0_2$ when coal is burned. Trace amounts of mercury (Figure 10.46) and radioactive materials are also released into the atmosphere-when coal is burned. Anthracite (which is about 98% carbons) is the mail desirable types of coal because of its high heat contend and-low sulfur content (Figure10.47). However, because it takes much longer to form, it is less common and therefore more expensive than other types of coal.

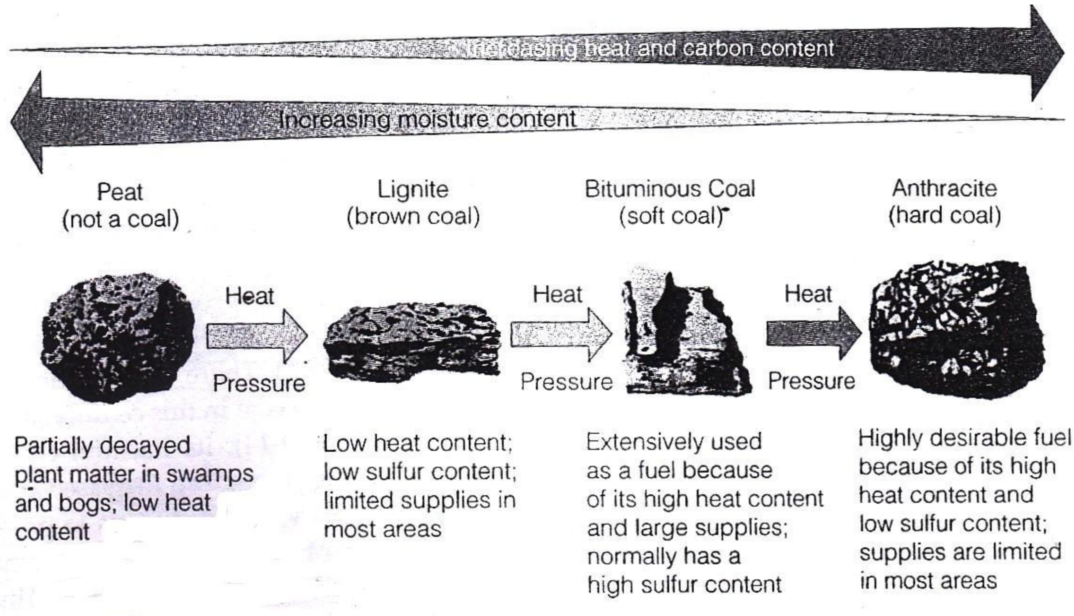


Figure10.47: ***Natural capital:*** **stages in coal formation over millions of years. Reat is a soil material made of moist, partially decomposed organic matter. Lignite and bituminous coal are sedimentary rocks, whereas anthracite is a metamorphic rock**

Some coal is extracted underground by miners working in tunnels and shafts. Such mining is one of the world's most dangerous occupations because of accidents and black lung disease (caused by prolonged inhalation of coal dust particles). When coal lies close to the earth's surface, it is extracted by *area strip mining* on flat terrain and *contour strip mining* on hilly or mountainous terrain. In some cases, entire mountaintops are removed to expose seams of coal under the mountains. After coal is removed, it is transported.(usually by train) to a processing plant, where it is broken up, crushed and washed to remove impurities. After the coal is dried it is shipped (again usually by train) to users, mostly power plants and industrial plants.

How Is Coal Used, and Where Are the Largest Supplies? Coal provides about 22% of the world's commercial energy (23% in the United States). It is burned to generate 62% of the world's electricity (51% in the United States) and make 75% of its steel. With current technology and prices the United States has 25% of global proven reserves. Russia has 16%, China 12%, and India 9%. Almost half of global coal consumption takes place in the United States (24%) and China (23%).

How Long Will Coal Supplies Last? Coal is the world's most abundant fossil fuel. Identified world reserves of coal should last at least 225 years at the current usage rate and 65 years if usage rises 2% per year. The world's unidentified coal reserves are projected to last about 900 years at the current consumption rate and 149 years if the usage rate increases 2% per year. Thus identified and unidentified supplies of coal could last the world for 214-1,125 years, depending on the rate of usage. China, with 12% of the world's reserves, has enough coal to last 300 years at its current rate of consumption. Identified U.S. coal reserves should also last about 300 years at the current consumption rate, and unidentified U.S. coal resources could extend those supplies for perhaps another 100 years, at a higher cost.

What Is the Future of Coal? Figure10.48 lists the advantages and disadvantages of using coal as an energy resource. Coal is very abundant. But it has the highest environmental impact of any fossil fuel in each of the following categories: land disturbance (Figure10.31 and Figure 10.35); air pollution; $C0_2$ emissions (Figure 10.41), accounting for about 36% of the world's annual emissions; release of particles of toxic mercury when burned; release of thousands of times more radioactive particles into the atmosphere per unit of energy produced than a normally operating nuclear power plant; and water pollution. Each year in the United States alone, air pollutants from coal burning kill thousands of people (estimates range from 65,000 to 200,000), cause at least 50,000 cases of respiratory disease, and result in several billion dollars of property damage. Coal is also difficult and expensive to transport very far because it is heavy and bulky.

Energy costs from a new coal power plant in the United States are low (around 4c per kilowatt-hour), mostly because of large government subsidies. However, according to a 2001 study by Stanford University researchers, this cost doubles to around 8c per kilowatt-hour if health and environmental costs are included. In contrast, the average cost of wind energy in the United States—including its environmental and health costs— is about 4 per kilowatt-hour. New ways have been developed to burn coal more cleanly and efficiently, such as fluidized-bed combustion and coal gasification. With large government subsidies these technologies may be phased in over the next several decades. But they do little to reduce $C0_2$ emissions that are considered the major culprit in projected global warming and a major drawback of coal as an energy resource **(**Figure 10.49).

Most analysts project a leveling off of coal use over the next 40-50 years followed by a decline in its use (Figure10.35). There are three major reasons for a shift away from coal in this century: it’s high CO_2 emissions (Figure 10.41), its harmful environmental and human health effects, and increased availability of less environmentally harmful ways to produce electricity

(Figure 10.50) (such as burning natural gas in combined-cycle gas turbines, wind energy, solar cells, and hydrogen).

What Are the Advantages and Disadvantages of Converting Solid Coal into Gaseous and Liquid Fuels? Solid coal can be converted into synthetic natural gas (SNG) by coal gasification (Figure 3.49) or into a liquid fuel such as methanol or synthetic gasoline by coal liquefaction. Figure 3.50 lists the advantages and disadvantages of using these *synfuels* produced from coal. Unless it receives huge government subsidies, most analysts expect coal gasification to play only a minor role as an energy resource in the next 20-50 years.

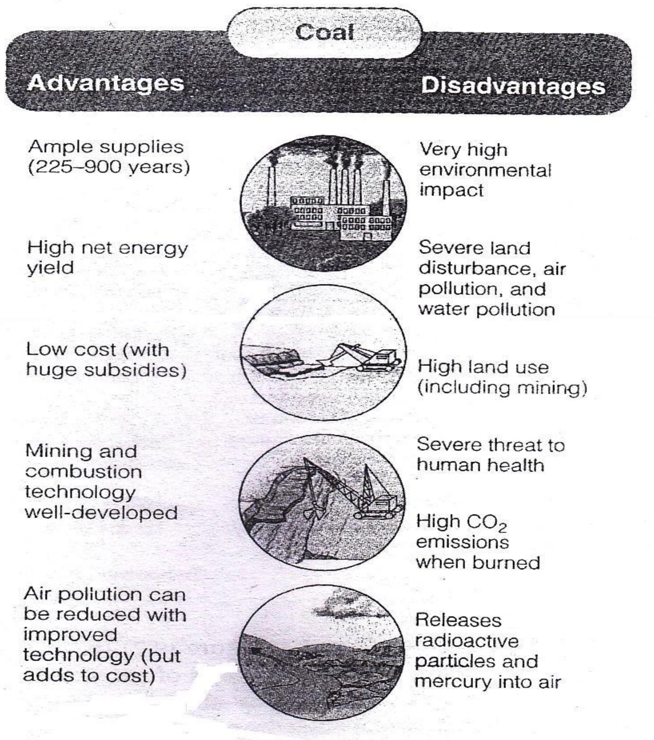


Figure 10.48: Advantages and Disadvantages of using coal as an energy resource

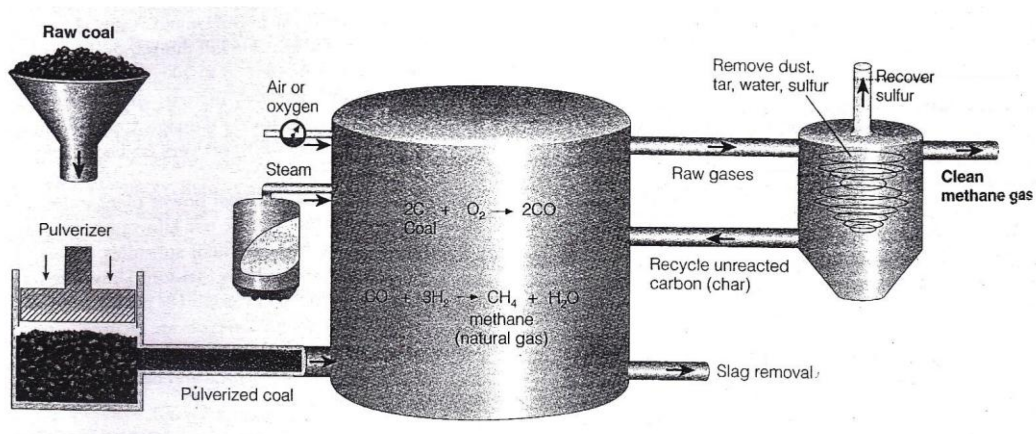


Figure 10.49: Coal signification. Generalized view of one method for converting solid coal into synthetic natural gas (methane)

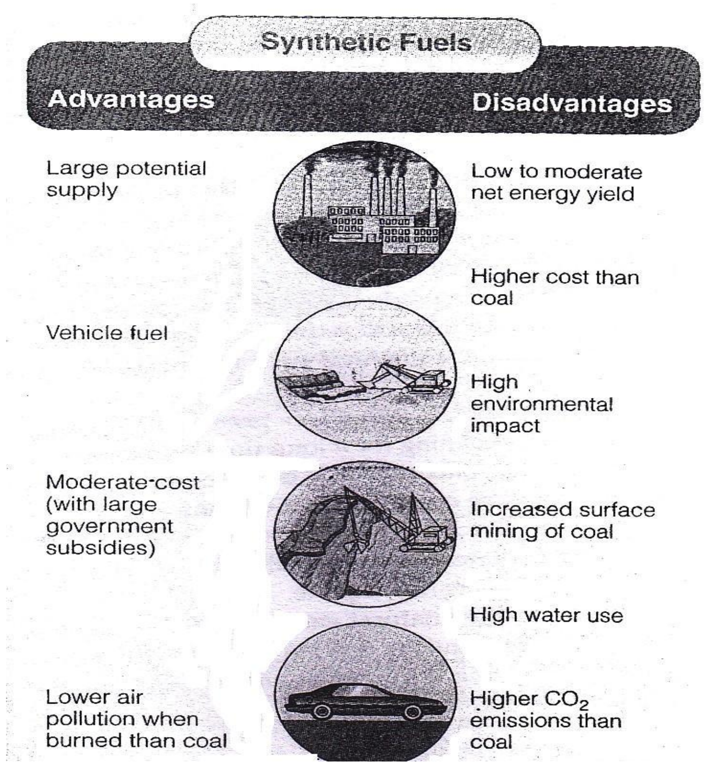


Figure 10.50: Trade offs; Advantages and Disadvantages of using synthetic natural gas (SNG) and other liquid synfuels produced from coal

Nuclear Energy

How Does a Nuclear Fission Reactor Work? To evaluate the advantages and disadvantages of nuclear power we need to know how a conventional nuclear power plant and its accompanying nuclear fuel cycle work. In a nuclear fission chain reaction, neutrons split the nuclei of atoms such as uranium-235 and plutonium-239 and release energy mostly as high-temperature heat as a result of a chain reaction. In the reactor of a nuclear power plant, the rate of fission is controlled and the heat generated is used to produce high-pressure steam, which spins turbines that generate electricity.

Light-water reactors (LWRs) such as the one diagrammed in Figure10.50 produce about 85% of the world's nuclear-generated electricity (100% in the United States). An LWR plant has the following key parts:

- *Core*, containing 35,000-70,000 long, thin fuel rods, each packed with fuel pellets. Each pellet is about one third the size of a cigarette and contains the energy-equivalent of 0.9 metric ton (1 ton) of coal. As the fuel is used up, the spent fuel rods are removed and re-placed with new ones.
- *Uranium oxide fuel*, consisting of about 97% non-fissionable uranium-238 and 3%

fissionable uranium-235. To create a suitable fuel, the concentration of uranium-235 in the ore is increased (enriched) from 0.7% (its natural concentration in uranium ore) to 3% by removing some of the uranium-238.

- *Control rods,* which are moved in and out of the reactor core to absorb neutrons and thus regulate the rate of fission and amount of power the reactor produces.
- *Moderator,* which slows down the neutrons emitted by the fission process so the chain reaction can be kept going. This is a material such as liquid water (75% of the world's reactors, called *pressurized water reactors,* Figure10.51), solid graphite (20% of reactors), or heavy water (deuterium oxide, D_20; 5% of reactors). Graphite-moderated reactors (used in the ill-fated Chernobyl plant; Figure 3.30) can also produce fissionable plutonium-239 for nuclear weapons.
- *Coolant,* usually water, which circulates through the reactor's core to remove heat (to keep fuel rods and other materials from melting) and produce steam for generating electricity.

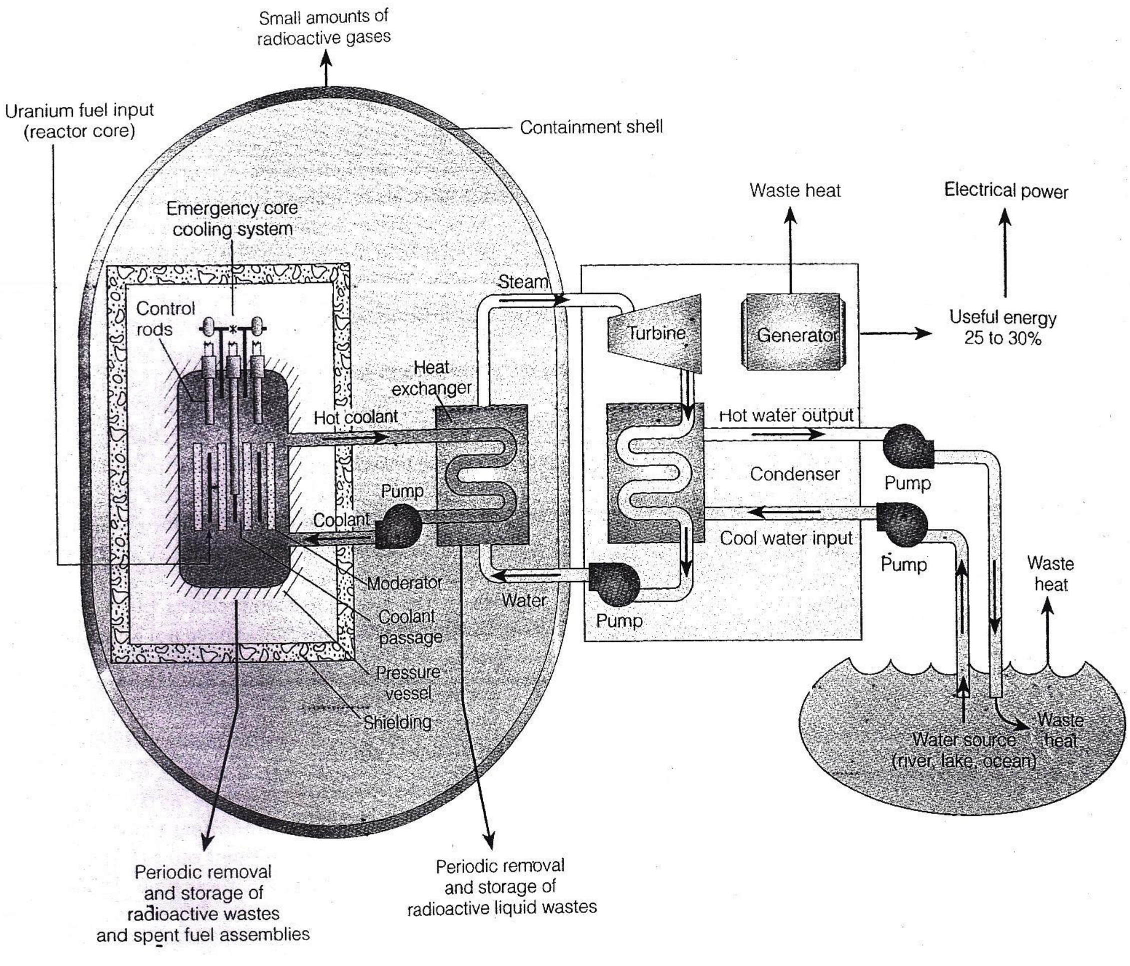


Figure 10.51: Light water moderated and cooled nuclear power plant with a pressurized water reacter

- *Containment vessel* to keep radioactive materials from escaping into the environment in case of an internal explosion or core meltdown within the reactor or an external threat to the reactor such as a plane crashing into the containment vessel. Containment
- Vessels typically consist of a 1.2-meter (4-foot) steel-reinforced concrete wall along with a steel liner. A U.S. reactor survived a head-on test crash of a military jet without major damage. However it is not known whether the typical containment shell would remain intact after a head-on crash of a large commercial airliner loaded with jet fuel.
- *Water-filled pools* or *dry casks* for on-site storage of highly radioactive spent fuel rods removed when re actors are refueled. Most spent fuel rods are stored in 12-meter- (40-foot-) deep pools of boron-treated water to shield against radiation and to keep the fuel from heating up, catching fire, and releasing radioactive materials into the environment. Spent-fuel pools or casks are in a separate building not nearly as well protected as the reactor core and are much more vulnerable to a head-on crash from even a small plane and to a terrorist attack. The long-term goal is to trans port spent fuel rods and other long-lived radioactive wastes to an underground facility where they must be stored safely for 10,000-240,000 years until their radioactivity falls to safe levels.

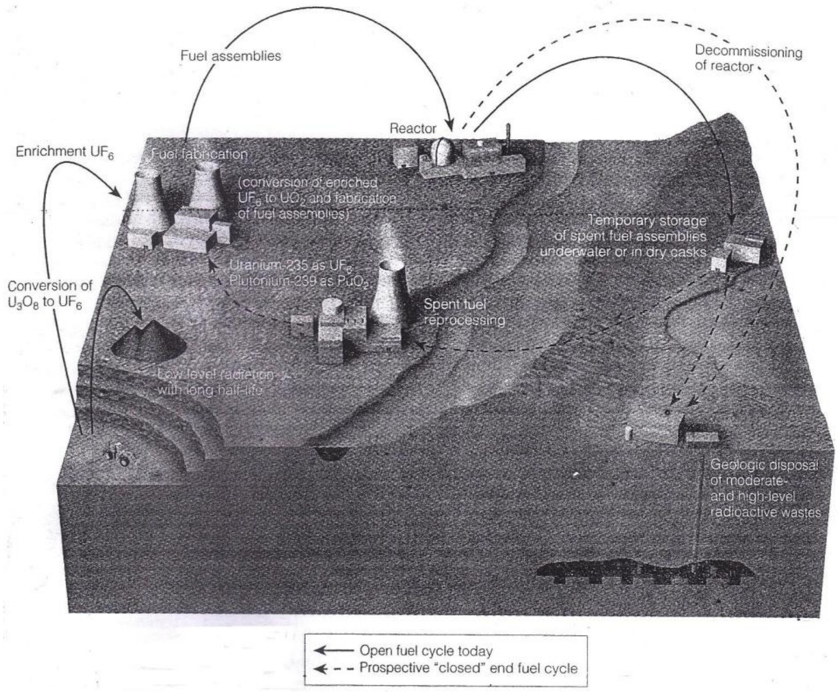


Figure 10.52: The nuclear fuel cycle

Nuclear power plants, each with one or more reactors, are only one part of the nuclear fuel cycle (Figure 10.52). Unlike other energy resources, nuclear energy results in the production of intensely radioactive materials that must be stored safely for 10,000-240,000 years. In the *closed cycle*

(Figure 3.52, dotted line), the fissionable isotopes uranium-235 and plutionium-239 are removed from spent fuel assemblies for reuse as nuclear fuel.

In the *open cycle* (solid line, Figure 10.52) these isotopes are not removed by reprocessing the nuclear wastes and are buried in an underground disposal facility. These wastes must be stored safely for about 240,000 years. Currently, these isotopes are rarely re moved from spent fuel rods and other nuclear wastes because of high costs and the potential use of the removed isotopes in nuclear weapons. In evaluating the safety and economic feasibility of nuclear power, energy experts and economists caution us to look at this entire cycle, not just the nuclear plant itself.

What Happened to Nuclear Power? Studies indicate that U.S. utility companies began developing nuclear power plants in the late 1950s for three reasons. *First,* the Atomic Energy Commission (which had the conflicting roles of promoting and regulating nuclear power) promised utility executives that nuclear power would produce electricity at a much lower cost than coal and other alternatives. Indeed, President Dwight D. Eisenhower declared in a 1953 speech that nuclear power would be "too cheap to meter."

Second, the government (taxpayers) paid about one-fourth of the cost of building the first group of Commercial reactors and guaranteed there would be no cost over runs. *Third,* after insurance companies refused to insure nuclear power, Congress passed the Price-Anderson Act to protect the U.S. nuclear industry and utilities from significant liability to the general public in case of accidents. In the 1950s, researchers predicted that by the year 2000, at least 1,800 nuclear power plants would supply 21% of the world's commercial energy (25% in the United States) and most of the world's electricity.

However, after more than 50 years of development, enormous government subsidies, and an investment of $2 trillion, these goals have not been met. Instead, by 2001,436 commercial nuclear reactors in 32 countries were producing 6% of the world's commercial energy and 16% of its electricity. Since 1989, the growth in electricity production from nuclear power has essentially leveled off and is projected to decrease by 2020 (Figure10.32). Germany (which gets 31% of its electricity from nuclear power), Sweden (39%), Belgium (60%), the Netherlands, and Spain plan to phase out nuclear power over the next 20-30 years. Nuclear power is also losing some of its appeal in France, Japan, and China—all once solid supporters of its increased use. France and China (which has four reactors and is building nine more) have put a moratorium on building new nuclear plants, and France has cut its long-term target for building new reactors in half.

No new nuclear power plants have been ordered in the United States since 1978, and ail 120 plants ordered since 1973 have been canceled. In 2001, there were 104 licensed and operating commercial nuclear power reactors in 31 states—most in the eastern half of the country. These reactors generated about 21% of the country's electricity and 8% of its total energy use. This percentage is expected to decline over the next two to three decades as existing plants wear out and are retired (Figure10.34).

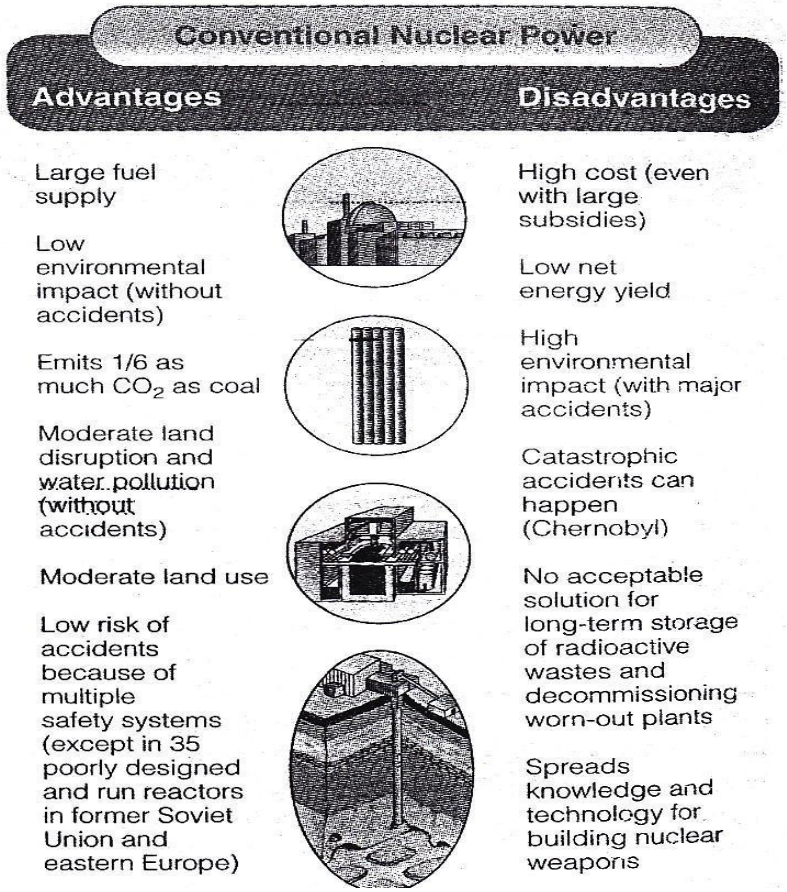


Figure 10.53: Trade offs; Advantages and Disadvantges of using nuclear power to produce electricity. This evaluation includes the entire nuclear fuel cycle

According to energy analysts and economists, there are several major reasons for the failure of nuclear power to grow as projected. They include multibillion-dollar construction cost overruns, higher operating costs and more malfunctions than expected and poor management. Two other major setbacks have been public concerns about safety and stricter government safety regulations, especially after the accidents in 1986 at Chernobyl and in 1979 at Three Mile Island in Pennsylvania. Another problem is investor concerns about the economic feasibility of nuclear power. Also, concern has risen about the vulnerability of nuclear power plants to terrorist attack after destruction of the World Trade Center buildings in New York City on September 11, 2001.

What Are the Advantages and Disadvantages of conventional Nuclear Power? Figure 10.53 lists the major advantages and disadvantages of nuclear power. Using nuclear power to produce electric-it)' has some important advantages over coal-burning power plants (Figure 10.54).

How Safe Are Nuclear Power Plants and Other Nuclear Facilities? Because of the built-in safety features, the risk of exposure to radioactivity from nuclear power plants in the United States" and most other developed countries is extremely low. However, a partial or complete meltdown or explosion is possible, as accidents at the Chernobyl nuclear power plant in Ukraine and the Three Mile Island plant in Pennsylvania have taught us. The U.S. Nuclear Regulatory Commission (NRC) estimates there is a 15—45% chance of a complete core meltdown at a U.S. reactor during the next 20 years. The NRC also found that 39 U.S. reactors have an 80% chance of failure in the containment shell from a meltdown or an explosion of gases inside the containment structures.

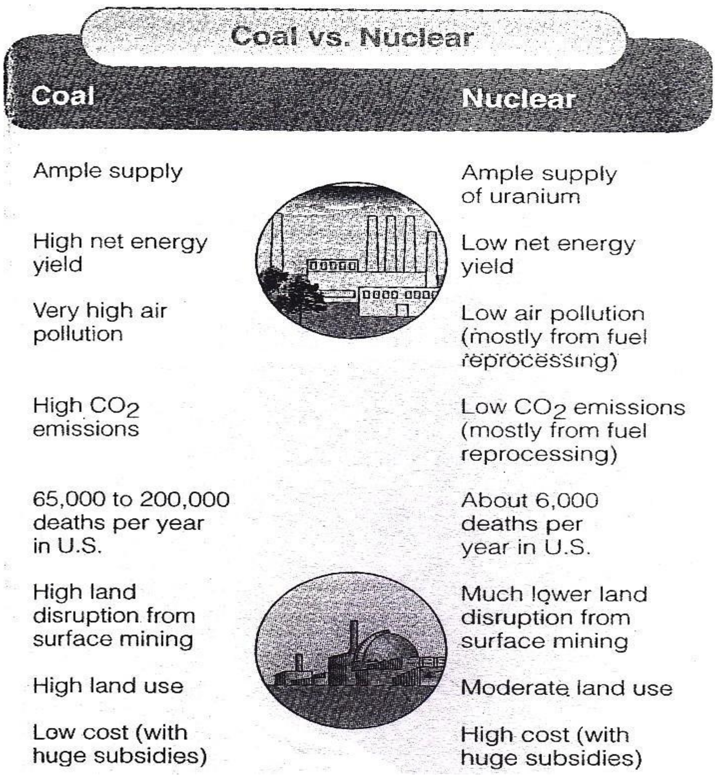


Figure 10.54: Trade offs; comparison of the risks of using nuclear power and coal burning plants to produce electricity

Another concern is that 27 of 57 operating nuclear power plants in the United States failed mock, ground-based terrorist security tests made by the Nuclear Regulatory Commission prior to 1998. The NRC contends that the security weaknesses revealed by these tests have been corrected. But many nuclear power analysts are unconvinced and note that the government has stopped staging mock attacks on nuclear plants that reveal security shortcomings.

The 2001 destruction of New York City's two World Trade Center towers by terrorist attacks raised fears that similar attack by a large plane loaded with fuel could break open a reactor's containment shell (Figure 3.51), set off a reactor meltdown, and creates a major radioactive disaster. Nuclear officials believe that U.S. plants could survive such an attack. But a 2002 study by the Nuclear Control Institute found that the U.S. nuclear plants were not designed to withstand the crash of a large jet traveling at the impact speed of the two hijacked airliners that hit the World Trade center. This is not surprising because in 1982 the U.S. Nuclear. Regulatory Commission ruled that owners of nuclear power plants did not have to design the plants to survive threats such as kamikaze airliner crashes. According to the NRC, requiring such construction would make nuclear electricity too expensive to be competitive.

A 2002 report by Congressman Ed Markey of Massachusetts, based on analysis of NRC data, said that guards at U.S. nuclear plants are underpaid, undertrained, and incapable of repelling a serious ground attack by terrorists. It also said that 21 U.S. nuclear reactors are within 8 kilometers (5 miles) of an airport. In addition, a small or large aircraft or ground attack that cut off electrical power to a reactor could cause a core meltdown within about two hours without crashing into the reactor. David Freeman was President Jimmy Carter's energy adviser, CEO of several major power companies, and is now energy adviser to the governor of California. In 2002 he warned, "The danger of penetration into a nuclear reactor—which is difficult but not impossible is so horrendous that we've got to put out of our minds the building of any more nuclear power plants."

Throughout the world, nuclear scientists and government officials urge the shutdown of 35 poorly designed and poorly operated nuclear reactors in some republics of the former Soviet Union and in Eastern Europe. This is unlikely without economic aid from the world's developed countries. In the United States, there is widespread public distrust of the ability of the NRC and the Department of Energy (DOE) to enforce nuclear safety in commercial (NRC) and military (DOE) nuclear facilities. Congressional hearings in 1987 uncovered evidence that high-level NRC staff members destroyed documents and obstructed investigations of criminal wrongdoing by utilities, suggested ways utilities could evade commission regulations, and provided utilities and their contractors with advance notice of so-called surprise inspections. In 1996, George Galatis, a respected senior nuclear engineer, said, "I believe in nuclear power but after seeing the NRC in action I'm convinced a serious accident is not just likely, but inevitable. . . . They're asleep at the wheel."

The nuclear power industry claims that nuclear power plants in the United States have not killed anyone and cause far less environmental harm than coal-burning plants (Figure 3.54).

However, according to U.S. National Academy of Sciences estimates, U.S. nuclear plants cause 6,000 premature deaths and 3,700 serious genetic defects, each year. If correct, this annual death toll is much smaller than the 65,000-200,000 deaths per year caused by coal-burning plants in the United States. However, critics point out that the estimated annual deaths from both of these types of plants are unacceptable, given the availability of much less —harmful alternatives such as combined-cycle natural gas turbines and wind power and eventually solar cells and hydrogen. Despite these concerns, in 2002 the Bush administration—with strong lobbying from the nuclear power industry—was pushing to build 25-50 new nuclear power plants in the United States within the next two decades.

What Do We Do with Low-Level Radioactive Waste? Each part of the nuclear fuel cycle (Figure 3.52) produces low-level and high-level solid, liquid, and gaseous radioactive wastes with various half-lives. Wastes classified as *low-level radioactive wastes* give off small amounts of ionizing radiation and must be stored safely for 100-500 years before decaying to safe levels. From the 1940s to 1970, most low-level radioactive waste produced in the United States (and most other countries) was put into steel drums and dumped into the ocean; the United Kingdom and Pakistan still dispose of their low-level radioactive wastes in this way.

Today, low-level waste materials from commercial nuclear power plants, hospitals, universities, industries, and other producers in the United States are put in steel drums and shipped to the two remaining regional landfills run by federal and state governments. Attempts to build new regional dumps for low-level radioactive, waste using improved technology have met with fierce public opposition.

What Is High-Level Radioactive Waste? *High level radioactive wastes* give off large amounts of ionizing radiation for a short time and small amounts for a long time. Such wastes - must be stored safely for at least 10,000 years and about 240,000 years if plutonium-239 (with a half-life ⁻of 24,000 years) is not removed by reprocessing (Figure 3.52).

Case Study: How Safe Is High Level Radioactive Waste Stored at U.S. Nuclear Power Plants?

Most high-level radioactive wastes are spent fuel rods from commercial nuclear power plants. Some of these rods are stored in metal casks but most are stored in pools of boron-treated water at plant sites. A spent-fuel pool typically holds five to ten times more long-lived radioactivity than the radioactive core inside -a plant's reactor.

Suppose that water drained out of a spent-fuel pool or that a dry storage cask ruptured—because of events such as earthquake, airplane impact, or terrorist act. Then the highly radioactive and thermally hot fuel would be exposed to air and steam. This would cause the zirconium outer cover of the fuel assemblies to catch fire and burn fiercely. The NRC acknowledges that such-a fire could not be extinguished and would burn for days. This would release large amounts of radioactive materials into the atmosphere, contaminate large areas with radioactivity for many decades, and create economic and psychological havoc.

Unlike the reactor core with its thick concrete protective dome, spent-fuel pools have little protective cover. At about one-third of U.S. power plants the reactor is in one building and the spent-fuel pool is in a separate building with a thin corrugated metal roof and walls. At the rest of the plants, the spent-fuel pool is in a concrete building attached to the reactor building with the concrete offering much less protection than the much thicker concrete containment shell surrounding the reactor. The pools have back-up cooling systems to help prevent a fire, but these systems could malfunction or be destroyed by a terrorist attack. Dry casks stored in buildings outside a reactor are safer than storage in water pools. However, the casks can be ruptured by a severe attack.

A deliberate crash by a small airplane or an attack by a group of suicidal terrorists could drain a pool or rupture a dry cask containing spent fuel rods and cause a massive release of radioactivity. After the September 11 attacks in 2001, the Federal Aviation Administration banned small planes from flying over most U.S. nuclear plants, but these restrictions were lifted on November 6, 2001: Studies in 2002 by the Institute for Resource and Security Studies and the Federation of American Scientists projected serious harm from possible terrorist attacks on spent-fuel storage areas at many U.S. nuclear power plants. Here are two examples.

Suppose an accident or sabotage released all radioactive material in the spent-fuel rods in the storage pool at the Millstone Unit 3 reactor in Connecticut. This would put five times more radioactive material into the atmosphere than the 1986 Chernobyl accident. About 145,000 square kilometers (55,900 square miles) — more than the area of New York State would be uninhabitable for at least 30 years because of radioactive contamination. Or suppose all the fuel in two spent-fuel storage pools at the Sharon Harris Nuclear Plant (near Raleigh, North Carolina) burned. This would release enough radioactive material to contaminate an area larger than the entire state for at least 30 years.

According to these studies, about 161 million people—57% of the U.S. population—live within 121 kilometers (75 miles) of 131 aboveground spent-fuel storage sites in 39 states (most in the eastern half of the United States). In addition, these studies warned that decommissioned nuclear power plants might be even more vulnerable to sabotage because they store large amounts of spent fuel and have fewer personnel than operating plants. U.S. nuclear power officials consider such events to be highly unlikely worst-case scenarios and question some of the estimates. They also contend that nuclear power facilities are very safe from such attacks.

What Should We Do with High-Level Radioactive Waste? After more than 50 years of research, scientists still do not agree on whether there is a safe method for storing high-level radioactive waste. Some scientists believe the long-term safe storage or disposal of high-level radioactive wastes is technically possible. Others disagree, pointing out it is impossible to demonstrate that any method will work for the 10,000-240,000 years of fail-safe storage needed for such wastes. Following are five of the proposed methods and their possible drawbacks.

Bury it deep underground. This favored strategy is under study by all countries producing nuclear waste. In 2001, the U.S. National Academy of Sciences concluded that the geological repository option is the only scientifically credible long-term solution for safely isolating such wastes. However, according to an earlier 1990 report by the U.S. National Academy of Sciences, "Use of geological information to pretend to be able to make very accurate predictions of long-term site behavior is scientifically unsound."

Shoot it into-space or into the sun. Costs would be very high, and a launch accident—like the explosion of the space shuttle Challenger—could disperse high-level radioactive wastes over large areas of the .earth's surface. This strategy has been abandoned for now. Bury it under the Antarctic ice sheet or the Greenland ice cap. The long-term stability of the ice sheets is not known. They could be destabilized by heat from the wastes, and retrieving the wastes would be difficult or impossible if the method failed. This strategy is prohibited by international law.

Dump it into descending subduction zones in the deep ocean. However, wastes eventually might be spewed out somewhere else by volcanic activity and containers might leak and contaminate the ocean before being carried downward. Also, retrieval would be impossible if the method did not work. This strategy is prohibited by international law. Bury it in thick deposits of mud on the deep-ocean floor in areas that tests shows have been geologically stable for 5 million years. The waste containers eventually would corrode and release their radioactive contents. This approach is prohibited by international law. Change it into harmless, or less harmful, *isotopes.* Currently no way exists to do this. Even if a method was developed, costs probably would be very high, and the resulting toxic materials and low-level (but very long-lived) radioactive wastes would still need to be disposed of safely.

Case Study: What Should Be Done with High-Level Radioactive Wastes in the United States?

In 1985, the U.S. Department of Energy (DOE) announced plans to build a repository for underground storage of high-level radioactive wastes from commercial nuclear reactors on federal land in the Yucca Mountain desert region, 160 kilometers (100 miles) northwest of Las

Vegas, Nevada. By 2002, tire federal government had spent about $7 billion evaluating the site as a permanent under ground repository. The proposed facility (Figure 10.55) is expected to cost at least $58 billion to build (financed partly by a tax on nuclear power). It is scheduled to open by 2010.

In 2002, scientists working on the site released a report finding nothing to disqualify the site as a safe place to store high-level radioactive wastes. A number of scientists and energy analysts disagree with this assessment. For example, according to a December 2002 report by Congress's General Accounting Office, any decision to approve the site would be "premature" because 293 scientific questions about safety have not been answered.

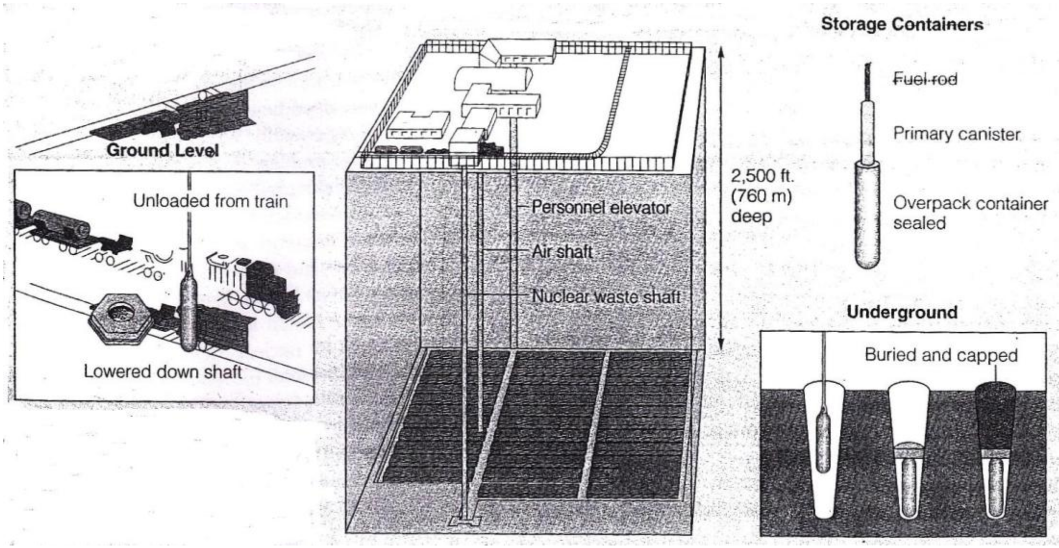


Figure 10.55: Solutions; general design for deep underground permanent storage of high level radio active wastes from commercial nuclear power plants in the United States

Some scientists argue that it should never be allowed to open. They are concerned that rock fractures may allow water to leak into the site and corrode casks holding radioactive waste. They also point out a nearby active volcano and 32 active earthquake fault lines running through the site—an unusually high number. In 1998, Jerry Szymanski, formerly the DOE's top geologist at Yucca Mountain and now an outspoken opponent of the site, said that if water flooded the site it could cause an explosion so large that "Chernobyl would be small potatoes. "In January 20o2 the Nuclear Waste Technical Review Board published its review of the site. According to this evaluation, it impossible to ensure that the wastes would remain safe for the thousands of years necessary to protect the environment and" human health.

Despite such concerns, in January 2002, the U.S. energy secretary found that the site is scientifically sound and recommended to President Bush and Congress that highly radioactive waste from the nation's nuclear power plants be deposited "under Nevada's Yucca Mountain. The secretary cited this as an important way to help protect wastes now stored at nuclear plants from possible terrorist attacks. This decision raised a storm of protest from Nevada elected officials and citizens (80% of them opposed, to the site) and others concerned about the safety of this approach. Opponents contend that the Yucca Mountain waste site should not be opened because it can decrease national (homeland) *security* for two major reasons. First, it would require about 56,000 shipments of wastes over much of the country—an average of five shipments a day for the estimated 30 years before-the site is filled—in trucks and rail cars that are difficult to protect from a terrorist attack.* Nevada's Senator Harry Reid calls a truck carrying waste to the site "a dirty nuclear bomb on 18 wheels waiting to happen."

Second, it would not decrease the possibilities of sabotage of nuclear wastes stored in pools and casks at the countries nuclear plant sites because the plants will be producing new wastes about as fast as the old wastes are shipped out. By 2036, when the site may be filled, there will be about as much nuclear waste stored at nuclear plant sites as exists today. The DOE and nuclear power proponents say the risks of an accident or sabotage of a nuclear waste shipment is negligible. Opponents believe the risks are underestimated, especially after the events of September 11, 2001.

In 2002, the U.S. National Academy of Sciences in collaboration with Harvard and University of Tokyo scientists urged the U.S. government to slow down and rethink the nuclear waste storage process. These scientists contend that storing spent-fuel rods in dry-storage casks in well-protected buildings at nuclear plant sites is an adequate solution for a number of decades in terms of safety and national security. This would buy time to carry out more research on this complex problem and to evaluate other sites and storage methods that might be more acceptable scientifically and politically. Despite many objections from scientists and citizens, during the summer of 2002 Congress approved Yucca Mountain as the official site for storing the country's commercial nuclear wastes.

How Widespread Are Contaminated Radioactive Sites? In 1992, the EPA estimated that as many as 45,000 sites in the United States may be contaminated with radioactive materials—20,000 of them belonging to the DOE and the Department of Defense. Since 1992, the DOE has spent $60 billion on cleanup and estimates that the cleanup will cost taxpayers another $200 billion over the next 70 years (some analysts estimate $400-900 billion). According to a 2000 DOE report, more than two-thirds of 144 highly contaminated sites used to produce nuclear weapons will never be completely cleaned up and will have to be–protected and monitored for centuries. Some critics, question spending so much money on a problem ranked by scientific advisers to the EPA as a low-risk ecological problem and not among the top" high-risk human health problems.

The radioactive contamination situation in the United States pales in comparison to the legacy of nuclear waste and contamination in the republics of the former Soviet Union. Land in various parts of the former Soviet Union is dotted with areas severely contaminated by nuclear accidents, 25 operating nuclear power plants with flawed and unsafe designs, nuclear waste dump sites, radioactive waste-processing plants, and contaminated nuclear test sites. In addition, the government dumped nuclear wastes and retired nuclear-powered submarines into coastal waters.

A 1957 explosion of a nuclear waste storage tank at Mayak, a plutonium production facility in southern Russia, spewed 2.5 times as much radiation in to the atmosphere as the Chernobyl accident. Because of radioactive contamination, no one can live within about 2,600 square kilometers (1,000 square miles of the surrounding area. In addition, nearby Lake Karachay (which was a dumpsite for the facility's radioactive wastes between 1949 and 1967) is so radioactive that standing on its shores for about a 1 hour would be fatal.

What Can We Do with Worn-Out Nuclear plants? After approximately 15-40 years of operation, a nuclear reactor becomes dangerously contaminated with radioactive materials, and many of its parts are worn out. Unless the plant's life can be extended by expensive renovation, it must be *decommissioned* or retired (the last step in the nuclear fuel cycle, 1 Figure 3.52).

Scientists have proposed three ways to do this. *One* is to dismantle the plant and store its large volume of highly radioactive materials in high-level nuclear waste storage facilities (Figure 3.55), whose safety is questioned by many scientists. A *second* approach is to put up a physical barrier around the plant and set up full-time security for 30-100 years before the plant is dismantled. A *third* option is to enclose the entire plant in a tomb that must last for several thousand years. At least 228 large commercial reactors worldwide (20 in the United States) are scheduled for retirement by 2012. By 2033, all U.S. reactors will have to be retired, based on their original 40-year operating licenses. Some utility companies and the Bush administration have proposed extending the life of current reactors to 50-60 years. Opponents contend that extending the life of reactors could increase the risk of nuclear accidents in aging reactors.

What Is the Connection between Nuclear Reactors and the Spread of Nuclear Weapons?

Currently, 60 countries—1 of every 3 in the world—have nuclear weapons (at least 10 nations) or the knowledge and ability to build them. Information and fuel needed to build these nuclear weapons have come mostly from the research and commercial nuclear reactors that the United States and 14 other countries have been giving away and selling in the international marketplace for decades.

Some *good news* is that between 1986 and 2001, the number of nuclear warheads held by the world's five largest nuclear powers declined by 55% and further declines are expected by 2012. The *bad news* is that this still leaves enough nuclear weapons to kill everyone in the world at least 30 times. This also greatly increases the amount of bomb-grade plutonium-239 removed from retired nuclear warheads that must be kept secure from use in nuclear weapons.

What Is the Threat from "Dirty" Radioactive Bombs?

There is growing concern, especially after the September 11, 2001, terrorist attacks in the United States, about threats from explosions of so-called *dirty radioactive bombs.* A dirty bomb consists of an explosive such as dynamite mixed with or wrapped around some form of radioactive material that is not difficult or expensive to obtain. Such a conventional bomb with a small amount of radioactive material (that often would fit in a coffee cup) is fairly easy to assemble.

Such materials can be stolen from thousands of loosely guarded and difficult to protect sources or bought on the black market. One source is hospitals using radioisotopes (such as cobalt-60) to treat cancer, diagnose various diseases, and sterilize some types of medical equipment. Other sources include university research labs, and industries using radioisotopes to detect leaks in underground pipes, irradiate food, examine mail and other materials, and detect flaws in pipe welds and boilers. Radioactive materials are also found in smoke detectors (americium-241).

Detonating a dirty bomb at street level or on a rooftop does not cause a nuclear blast. But it could have a number of harmful effects depending on-the amount of explosive material used. For example, the blast and subsequent cancers could kill a dozen to 1,000 people in densely populated cities and spread radioactive material over several to hundreds of blocks. The blast would contaminate buildings and soil in the affected area for up to ten times the half-life of the isotope used unless areas are cleaned up at-great expense (billions of dollars). Cleanup would involve sandblasting or demolishing buildings, digging up asphalt and sidewalks, removing topsoil, and transporting the radioactive material to safe storage sites.

Affected areas would have to be evacuated for-many years, perhaps decades, including shutdown of all business and government agency offices. Prolonged contamination would discourage businesses and agencies from reopening in such areas. Finally, detonating a dirty bomb would cause intense psychological terror and panic throughout much of a country. As a result, terrorists would succeed in their primary objective. Here are the results of two simulations by the Federation of American Scientists and the Center for Strategic and International Studies (a Washington think tank). In one scenario, a dirty bomb is detonated in Manhattan using a small piece of cobalt-60 stolen from a food irradiation plant. The explosion would spread contamination over about 300 city blocks, kill up to 1,000 people, and render much of New York City uninhabitable for decades.

In another scenario, terrorists explode a pea-sized piece of radioactive cesium-137 (fairly easy to obtain from medical equipment) on the mall m Washington, D.C., near the National Gallery of Art. The blast would kill about 20 people and contaminate for decades a 1.6-kilometer (1-mile) swath of land that includes the U.S. Capitol, Supreme Court, and Library of Congress buildings. Since 1986, the NRC has recorded 1,700 incidents in the United States in which radioactive materials used by industrial, medical, or research facilities have been stolen or lost—an average of about 100 incidents per year. Since 1991, the International Atomic Energy Agency (IAEA) has detected 671 incidents of illicit trafficking in dirty-bomb materials.

Can Nuclear Power Reduce U.S. Dependence on Oil?

Some proponents of nuclear power in the United States claim it will help reduce dependence on imported oil. However, other analysts point out that use of nuclear power has little effect on U.S. oil use because oil produced only 2.9% of the electricity in the United States in 2001. Also, the major use for oil is in transportation, which would not be affected by increasing the use of nuclear power plants to produce electricity.

Can We' Afford Nuclear Power?

Experience has shown that nuclear power is an expensive way to boil water Jo produce electricity, even when huge government subsidies, partially shield it from free-market competition with other-energy sources. Costs rose dramatically in the 1970s and 1980s because of unanticipated safety problems and stricter regulations after the Three Mile Island and Chernobyl accidents. Estimates of the costs of producing nuclear power vary widely because of different variables used to make such calculations.

In 1995, the World Bank said that nuclear power is too costly and risky. *Forbes* business magazine has called the failure of the U.S. nuclear power program "the largest managerial disaster in U.S. business history, involving $1 trillion in wasted investment and $10 billion in direct losses to stockholders." Some *good news* is that in recent years, the operating cost of many U.S. nuclear power plants has dropped, mostly because of less downtime. However, environmentalists and economists point out that the cost of nuclear power must be based on the entire nuclear fuel cycle (Figure 3.52), not merely the operating cost of individual plants. This includes mining and producing nuclear fuel, nuclear waste disposal, and decommissioning of worn-out plants. According to these analysts, when these costs are included the overall cost of nuclear power is very high (even with huge government subsidies) compared to many other energy alternatives.

Can We Develop New and Safer Types of Nuclear Reactors?

The U.S. nuclear industry hopes to persuade the federal government and utility companies to build hundreds of smaller second-generation plants using standardized designs, which they claim are safer and can be built more quickly (in 3-6 years) These advanced light-water reactors (ALWRs) have built;, in passive safety features designed to make explosions or the release of radioactive emissions almost impossible However, according to Nucleonics Week, an important nuclear industry publication, "Experts are flatly unconvinced that safety has been achieved—or even sub-stantially increased—by the new designs." In addition these new designs do not eliminate the threats from the use of nuclear fuel in nuclear weapons and the expense and hazards of long-term radioactive waste storage and power plant decommissioning.

Is Breeder Nuclear Fission a Feasible Alternative?

Some nuclear power proponents urge the development and widespread use of breeder nuclear fission reactors, which generate more nuclear fuel than they consume by converting non fissionable ura-nium-238 into fissionable plutonium 239. Because breeders would use more than 99% of the uranium in .ore deposits, the world's known uranium reserves would last at least 1,000 years, and perhaps several thousand years.

However, if the safety system of a breeder reactor fails, the reactor could lose some of its liquid sodium coolant, which ignites when exposed to air and reacts explosively if it comes into contact with water. This' could cause a runaway fission chain reaction and perhaps a nuclear explosion powerful enough to blast open the containment building and release a cloud of highly radioactive gases and particulate matter. Leaks of flammable liquid sodium can also cause fires, which have happened with all experimental breeder reactors built so far. In addition, existing experimental breeder reactors produce plutonium so slowly, it would take 100-200 years for them to produce enough to fuel a significant number of other breeder reactors. In 19% the United States ended government-supported research for breeder technology after providing about $9 billion in research and development funding.

In December 1986, France opened a commercial size breeder reactor. It was so expensive to build and operate that after spending $13 billion, the government spent another $2.75 billion to shut it down permanently in 1998. Because of this experience, other countries have abandoned their plans to build full-size commercial breeder reactors.

Is Nuclear Fusion a Feasible Alternative?

Nuclear fusion in the sun provides 99% of the earth’s energy. For decades, scientists have hoped that controlled nuclear fusion will provide an almost limitless source of high-temperature heat and electricity to supply most of the world's commercial energy. Research has focused on the D-T nuclear fusion reaction, in which two isotopes of hydrogen—deuterium (D) and tritium (T)—fuse at about 100 million (180 million).

According to a 2001 Department of Energy task I force chaired by Vice President Dick Cheney, fusion energy has a number of important advantages. It includes no emissions of conventional air pollutants and carbon dioxide. Because the hydrogen isotopes involved in the fusion reaction could be obtained from water, the fuel supply would be essentially unlimited. Some short lived radioactive wastes would require burial and protection for about 100 years much less than the 10,000-250,000 years needed to store such wastes produced by conventional nuclear fission.

There would be no risk of meltdown or release of large amounts of radioactive materials from a terrorist attack because only a small amount of fuel is present in the system at any time. There would also be little risk from additional proliferation of nuclear, weapons because bomb-grade materials (such as enriched uramum-235 and plutomum-239) are not required for fusion energy. Fusion power could also be used to destroy toxic wastes. Finally, fusion power plants could supply unlimited energy to produce electricity for ordinary use and to decompose water and produce the hydrogen gas needed to run a hydrogen economy by the end of this century (Figure 3.35).

This sounds great, but what is the catch? Why don't we already have fusion energy? The bad news is that after 50 years of research and huge expenditures of mostly government funds, controlled nuclear fusion is still in the laboratory stage. None of the approaches tested so far have produced more energy than they use. In 1989, two chemists claimed to have achieved .deuterium-deuterium (D-D) nuclear fusion at room temperature using a simple apparatus, but subsequent experiments have not substantiated their claim. Some scientists still hope to develop low-temperature null clear fusion, but most nuclear physicists are skeptical that it can be done.

If researchers can eventually get more energy out of nuclear fusion than they put in, the next step would be to build a small fusion reactor and then scale it up to commercial size. This is an extremely difficult engineering problem. Also, the estimated cost of building Band operating a commercial fusion reactor (even with huge government subsidies) is several times that of a comparable conventional fission reactor. Proponents, including the Bush administration, contend that with greatly increased federal funding, a commercial nuclear fusion power plant might be built by 2030 or perhaps by 2020 (with emphasis on developing a new technique called muon-catalyzed fusion). However, many energy experts do not expect nuclear fusion to be a significant energy source until 2100, if then.

What Should Be the Future of Nuclear Power in the United States? Since 1948, nuclear energy (fission and fusion) has received about 58% of all federal energy research and development funds in the United States (compared to 22% for fossil fuels, 11% for renewable energy, and 8% for energy efficiency and conservation). Some analysts call for phasing out all or most government subsidies and tax breaks for nuclear fission power and using such funds to subsidize and accelerate the development of promising newer energy technologies. To these analysts, nuclear fission power is a. complex, expensive, inflexible, and centralized way to produce electricity that is too vulnerable to terrorist attack. They believe it is a technology whose time has passed in a world where electricity will increasingly be provided by small, decentralized, easily expandable power plants such as natural gas turbines, wind turbines, arrays of solar cells, and fuel cells.

According to investors and World Bank economic analysts, conventional nuclear power simply cannot compete in today's increasingly open, decentralized, and unregulated energy market-Proponents of conventional nuclear power and nuclear fusion, including the Bush administration, disagree. They argue that governments should .continue funding research and development and pilot plant testing of potentially safer and cheaper reactor designs along with Breeder fission and nuclear fusion. They argue that we need to keep these nuclear options available for use in the future if natural gas turbines, improved energy efficiency, hydrogen-powered fuel cells, wind turbines, and other renewable energy options fail to keep up with electricity demands and reduce CO, emissions to acceptable levels.

Conclusion

The conservation of the world's biodiversity is thus utterly dependent on the way in which we interact with and use the world's forests. A new method used in 2011, put the total number of species on Earth at 8.7 million, of which 2.1 million were estimated to live in the ocean and 68 percent of mammal species. About 60 percent of all vascular plants are found in tropical forests. Mangroves provide breeding grounds and nurseries for numerous species of fish and shellfish and help trap sediments that might otherwise adversely affect seagrass beds and coral reefs, which are habitats for many more marine species. The biodiversity of forests varies considerably according to factors such as forest type, geography, climate and soils – in addition to human use. Most forest habitats in temperate regions support relatively few animal and plant species and species that tend to have large geographical distributions, while the montane forests of Africa, South America and Southeast Asia and lowland forests of Australia, coastal Brazil, the Caribbean islands, Central America and insular Southeast Asia have many species with small geographical distributions.

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About the Book

The book is written in simple language so that the students can easily grasp the matter. Some important terms has been incorporated. So that the students may search the useful related for competitive examinations. In the recent years included in the syllabus of almost all Indian Universities in various subjects of Biology or Life Sciences as an independent evergreen subject. Exponential growth in many areas of basic fundamentals made it necessary in some cases to write several chapters on the same topic which was covered in a single chapter in the earlier book. Similarly, in the present volume, separate new chapters have been written on topics which in the earlier title either did not figure at all or were each covered very briefly as a part of a chapter. In the present book, for instance in separate chapters have been written on new topics. The students of Biology at the post graduate (P.G.) under graduate (U.G.) levels need the recent Global changes and developments. This book will help them to understand the coneptes very easily.

About Authors

Dr. Mandaloju Venkateshwarlu

Dr. Mandaloju Venkateshwarlu obtained his M.Sc. (1995) and Ph.D. Degree in Botany from Kakatiya University (1999). Best NSS volunteer (1991-1992) (For Social Work and Plantation) (Nick name of Chetla Venkanna), nearly above 4-5 lakhs plantation (1989-1999), Haritha Mithra, KU (1999), Editor in chief (AJBS) Senior Scientist & Honorary fellow FHAS, Life Member in CBEES, Advanced in Plant Sciences, Asian Journal of Bio Science, (Editorial Member) Natural and Environmental Pollution Technology, Indian Botanical Society, Member in IJSET, IJSEAT, IJSR, IOSR & Asia Pacific European Biochemical Society (Senior Member). He has contributed more than 105 papers in National and International Journal. He wrote and published 13 books and nine book chapters. His Areas of interest are Plant Tissue Culture and Plant Biotechnology, Plant Mutation Breeding, Cytology and Cytogenetics, Molecular Biology and Crop Improvement. He attended 75 National and 20 International Conferences and many Workshops.