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SOLAR ENERGY AND THE DEVELOPMENT OF APPROPRIATE TECHNOLOGY FOR UNDERDEVELOPED COUNTRIES

A CASE STUDY OF A STRATEGY FOR THE DEVELOPMENT OF BANGLADESH

by

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Major Professor

Dedicated to my parents

and to my wife who encouraged me and helped me through the entire process and without her help I could not have done it

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Prof. Gary Coates, Department of Architecture, KSU

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EVOLUTION OF THE INDUSTRIAL SOCIETY

If we look back over the history of the last ten centuries or so, it becomes apparent that economic growth is a phenomena as old as mankind. The stone age, the bronze age, the space and electronic age describes a stage of development in human civilization. The division between one stage and the next is often marked by a technological advance. Systems of production and distribution are determined by the society in which they evolve. The driving force behind industrial growth and the widespread use of technology was based on the development of scientific knowledge and the harnessing of cheap fossil fuels for energy. The Industrial Revolution was based on new methods of production coupled with an increase in the population due to the advancement of technology in health, sanitation and agriculture.

In the Western World, until the beginning of the Industrial Revolution, developments in the energy usage were not as significant as developments in material use, like tools, art, architecture, commerce and agriculture. As Lewis Mumford observes:

> All the praise of tool making and tool using that has been mistakenly applied to man's early development becomes purified from Neolithic times onward, and should even be

> magnified in evaluating the later achievements of handicraft. The maker and the object reacted one upon the other. Until modern times, apart from the esoteric knowledge of the priests, philosophers and astronomers, the greater part of human thought and imagination flowed through the hands. 1

The spread of technology in Europe from the fall of the Roman Empire to the seventeenth century was slow and Europe had to wait for the Industrial Revolution to lead it to the mechanical future. To make the Industrial Revolution work modern technology needed an engine that could convert energy source into useful work at higher efficiency than water-mills and windmills. These existing sources were static and limited to specific locations like fast running rivers and windy areas. Besides "the low pressur steam engine of the eighteenth century, converted only one percent of the energy content of wood and coal to power, while the rest was wasted as heat." [2]

1.1 Technology and Modern Civilization

The growth of population through advances in technology has been made possible because of the development of fossil fuel resources. The extraction of excessive energy and raw materials from the ecological system has reduced the capability of nature to support human society. With the depletion of the energy resources, industrial society could be sustained only through import of cheap resources from a distant location. The search

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[1] Lewis Mumford, Technics and Human Development, (New York: Harcourt Brace Jovanovich, 1967), p.268.

[2] Wilson Clark, Energy for Survival: The Alternative to Extinction, (New York: Anchor Press, 1974), p.8.

For colonies abroad was first as a source of raw materials and later on as markets for finished products. According to Hyman Rickover:

> With ships that could navigate high seas and arms that could outfire any hand weapon, Europe was powerful enough to build new nations in the western hemisphere gain political control over Asia and Africa from where she drew raw materials and energy to speed her industrialization and complement military dominance with economic and commercial supremacy.[3]

"The modern high energy society which followed in the wake of the Industrial Revolution and colonial expansion particularly after the First and Second World Wars led to the high energy monoculture society."[4] The general expansion of industrialization allowed Europe to import food, energy and resources from the colonies overseas and sustain the monoculture at home. As Jane Jacobs in the "Economy of Cities," states "the decline of Manchester in comparison to Birmingham during the Industrial Revolution was due to monoculture." The same was true for Ireland during the Irish potato famine which occurred a century ago. This is because monoculture is basically alien to the laws of nature in which everything is interrelated and connected with everything else.

1.2 Correlation between Energy and Technology

Since the dawn of human history and the evolution of the industrial society, man's activities have been governed by the laws of thermodynamics. In biology as in physics the laws have been supreme and energy as such is never created or destroyed. It is

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[3]Hyman G. Rickover, "Energy Resources and Our Future," (a speech presented before the Minnesota State Medical Association, St. Pauls, Minnesota.

[4]W. Clark, Energy for Survival: The Alternative to Extinction (New York: Anchor Press, 1974) p. 20

upgraded and converted by photosynthesis and the solar energy captured is transformed to another form in the food cycle. Each time such a conversion is made, substantial energy is dissipated in the form of heat and overall entropy increases according to the second law. In the process of cultural evolution human societies have carried on the process of energy upgrading. But unlike other animals who have been maintaining the natural balance, human societies have carried on energy upgrading to extreme limits. Industrial civilization has reached a stage where it is consuming its energy and resource base much faster than it can be replenished. On the earths ecology system Barry Commoner says that:

> Because the global ecosystem is a connected whole, in which nothing can be gained or lost and which is not subject to overall improvement, anything extracted from it by human effort must be replaced. Payment of this price cannot be avoided; it can only be delayed. [5]

In short the alternatives as proposed through the high energy society and reliance on monoculture, leads to a technology which is highly centralized and fueled by enormous outlay of energy. The results from this sort of society is that a victory by it would have neither victors nor vanquished.

The latter part of the twentieth century brought forth four major challenges which were hardly anticipated. The crisis today according to G.L. Tuve being in : "energy supply; environmental control; population crowding and shortage of food and materials."

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[5] Barry Commoner, The Closing Circle (New York: Knopf, 1971) p. 46.

Modern industrial society which was shaken by the oil embargo and the rise of oil prices following the Arab-Israeli War of 1973 has operated under the erroneous belief that the more energy resources used the better off the society is. "The correlation between the increasing use of energy with rise of economic productivity, though not determined according to an exact ratio, was the established axiom."[6] The philosophy which still holds sway in the industrialized world is that the living standard ought to be proportional to the highest ratio of mechanical power versus man-power. Mechanization through intensive energy use can be one measure of productivity but cannot be a measure of the quality of life. The relationship between Gross National Product; a monetary measure of all goods and services produced in a nation, and the level of energy consumption have been studied by Makhijani and Lichtenberg of University of California. According to them , high level of energy usage did not necessarily bring about higher incomes. They found that :

> Great Britain, Belgium, Australia, Germany, Denmark, France and New Zealand had levels of Gross National Product within ten percent range of each other, but New Zealand needed less than half the amount of energy to sustain a higher Gross National Product than Great Britain. [7]

Moreover per capita energy consumption and per capita gross national product has no relation to distribution of income level. This was true in the case of South Africa and the United States.

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[6] Wilson Clark, Energy for Survival: The alternatives to extinction, (New York: Anchor Press, 1974), p.68.

[7] Ibid, p.69.

The findings of Makhijani and Lichtenberg have been given further credence by G. Tyler Miller in his book "Replenish the Earth". According to him , rich and middle class Americans are the mega consumers and polluters who occupy more space, consume more of each natural resource, disturb the ecology more, and pollute directly and indirectly the land, air and water with thermal, chemical and radioactive wastes. The average American consumes 1100 times the amount of energy compared to that of a resident of Burundi. Even West Germany whose per capita gross national product exceeded that of the U.S.A. in 1973, consumes less than half the per capita energy of an average American. A future senario can be predicted according to the study done by Chester Kylstra and Jesse Boyles of the University of Florida. "Their study indicates that the methodology of the conventional energy/ GNP ratio is incomplete and misleading because it considers the gross energy instead of the net energy in the economy."[8] Net energy is the amount of energy a consumer receives in the final product (an automobile for example) rather than gross energy (the energy content of the barrel of oil before processing). According to the study, the overall productivity in the U.S. economy, defined as the ratio of net energy/ gross energy, is declining even though the output per man hour is increasing. The statistical message of the analysis is that emphasis on energy use and the rise in gross national product cannot be sustained indefinitely.

1.3 Limits to Growth

The computer model study done by the Club of Rome and as stated

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[8] Ibid, p. 69

in the report "The Limits to Growth" is another interesting finding." The study found that population, agriculture, natural resources development, industrial production and pollution are all in the dangerous curves of exponential growth."[9] The findings of the Club of Rome have been challenged by the advocates of the nuclear energy, who point out that the limits to growth did not take into consideration the supply of cheap energy through nuclear power. Unfortunately nuclear energy with its grave technological, ecological and high risk factor would hardly be able to provide the cheap energy it is expected to do. In spite of the arguments of both the pro and anti nuclear faction, the basic premise remains that the challenge is not to push economy by attempting the impossible task of perpetual growth, but rather to learn how to maintain the highest level of living that can be shared universally and sustained ecologically. According to Herman Daly, economics, like other sciences , should identify some impossible theorems. A good one according to him would be " A United States style, high level, mass consumption economy is impossible to achieve for a world of four billion people and even if by some miracle such a state were achieved it would be impossible to sustain." This is because the six percent of the world's population residing in the United States already requires over thirty percent of the world's annual production of nonrenewable resources to sustain its current level of living.

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[9] Dennis L. Meadows, Alternatives to Growth-I :Asearch for sustainable futures,(Ballinger Publishing Company, Cambridge, Massachusetts, 1977.)

1.4 Ecology and Pollution

Along with the pollution that fossil fuel causes is the effect it has on the climate of the earth. Intervention by human actions in the environment have effected the microclimate and the continuing development of high energy society may alter the macroclimate. A study of Man's Impact on Climate (SMIC) sponsored by the Massachusetts Institute of Technology in 1971 found that further increase in the use of fossil fuels would lead to an increase of 1.4°F on the surface temperature of the earth by the year 2000. Another serious climatic effect of increased petroleum use is the contamination of the oceans with thin films of oil which reduces the motion of the oceans surface and intensity of the short surface waves. "The long range danger may be the raising of the temperature of the oceans surface."[10] Economist Nicholas Georgescu-Roegen in his analysis of the relationship between thermodynamic science and economics sees the process in its full ramifications, as :

> A continuous transformation of low entropy into high entropy, that is into irrevocable waste or with a topical term into pollution .... The economic process is entropic : it neither creates nor consumes matter or energy, but only transforms low into high entropy. 11

The focal point of all environmental concerns is the relationship

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[10] Study of Man's Impact on Climate (SMIC), Inadvertent Climate Modification, (Cambridge, Massachusetts: The MIT Press, 1971.)

[11] Nicholas Georgescu-Roegen, The Entropy Law and the Economic Process, (Cambridge, Massachusetts: Harvard University Press, 1971.)

of the human population to the earth's environment. As Odum puts it:

> Support of man include all the necessary works that provide stability, reserves, protection and all the criss cross controls required to regulate his complex needs. Either we must retain the old network of hundreds of species of plants and animals which carried on these functions for man or set up new machinery to perform them on energy subsidy. 12

It is within the broad context of the high energy society of the developed countries beset with all its ramifications, that the industrialization and application of western technology to the lesser developed countries should be evaluated.

1.5 Technology and the Lesser Developed Countries (LDC's)

Technology is viewed by many of the leaders of the newly emerging nations as a key to national autonomy and status in the world community. Automotive plants, steel mills and nuclear reactors have all become status symbols of achievement regardless of economic costs.

> The leaders of the Third World share an urgent and understandable desire to make a gigantic leap across time to bypass slower and more natural processes of economic and scientific growth and place science at the service of an immediate technology - a technology of improved agriculture, of health & sanitation and of startling new methods in education and training. 13

It is a paradox that the nations of the developing world so endowed with raw materials, surplus labor and potential markets have in fact remained poor. According to the industrialized nations the

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[12] Howard T. Odum, Environment, Power and Society, (New York: Wiley, 1971.)

[13] David E. Apta,"New Nations and the Scientific Revolution", Bulletin of the Atomic Scientists-XVII, Feb. 1961, p.61.

Third World societies are primitive because they cannot absorb western methods and technology. But this reasoning has been refuted by the LDC's who state that their backwardness is due to past colonialism and the present international economic order. Through all the charges and counter charges an important fact cannot be denied that the cradles of civilization : Chinese Egyptian, Mesopotamian, Indo-Gangetic, Incan and Mayan empires were flourishing when the Western world were stagnating. Many parts of what is called today the underdeveloped countries were once the cultural and economically richest areas of the world.

The satisfaction of basic needs and the eradication of poverty is the primary concern of the developing world. The formation of economic plans and development strategies by these countries must be aimed at overcoming these centuries old deficiencies. Further confusion has been compounded by the identification of "growth" with "economic development." The most important aspect of development is the improvement of welfare among all groups and the equitable distribution of wealth.

> According to the World Bank, nearly half of the world's people live in relative or absolute poverty in conditions which are an insult to human dignity. Some 900 million people are estimated to subsist on incomes of less than $75 a year in an environment of squalor, hunger and hopelessness. Of these, 650 million live in absolute poverty on incomes of $50 or less in conditions so wretched and deprived as to defy any rational definition of human decency.[14]

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[14] Jan Tinbergen and others, "Reshaping the International Order: A report to the Club of Rome," E.P. Dutton & Co. Inc. New York, 1976.

The immense variety of circumstances that exists in the developing world has an impact on the perception of what comprises developmental needs. In spite of the fact that poverty is all pervasive and common among the developing countries, the solution is not singular. The argument that the gains of industrialization would trickle to the masses has been disproved by what has actually happened. The failure to meet the rising expectations of the great majority of the people leads to political subjugation. According to Hla Myint of the London School of Economics, the development of the Third World lacks a major component which have been identified as minimal domestic savings, little foreign exchange earnings and mass illiteracy. The problem with a development strategy that emphasizes the borrowing of foreign exchange to produce substandard and subsidized goods leads to foreign monetary control over capitalization at the expense of a more balanced use of domestic resources. The negative effects include excess productive capacity with neither home nor world market, overborrowing with heavy debt servicing, mechanization and underutilization of traditional surplus labor. Another basic problem has been on the emphasis on education for development. The unfortunate experience has been that education was concentrated either on liberal arts or in fields with limited national job opportunities which ultimately results in immigration.

Owens and Shaw identifies four steps that have characterized western efforts at encouraging the development of the lesser developed countries.

1. First was the period of past colonial effort in structuring democratic concepts and procedures in the belief that it would lead to self generating development movement.
2. The belief that education was the key, which on the contrary produced surplus graduates ill-equipped to solve the real problems.
3. The industrialization and application of western technology.
4. And finally the failure of development has been not so much in the technique but on the short-fall in quantity. 15

Since the goal of the developing countries is to catch up with the technology of the western nations in the shortest possible time, they have relied more and more on capital intensive industrialization as practiced in those countries. To understand the problems of this strategy one has to study the particular problems of an industrial society. The heart of an industrial society is its industries which rely on fossil fuel for their energy. Not only are the industrial nations dependent on fossil fuels for ninety five percent of their energy but all natural resources are being depleted at an exponential rate. It is unrealistic to expect fossil fuel extraction to grow exponentially until it suddenly drops to zero, instead fossil fuel recovery builds up to a peak and then declines. As a general rule no more than ten percent of an oil fields total reserve can be obtained in one year, without reducing the quantity that can ultimately be recovered. It is inaccurate

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[15] Owens and R. Shaw, Development Reconsidered, (Lexington, Max: Lexington Books, 1972).

to suppose that society will run out of energy, on the contrary long before the last barrel of oil is depleted, more energy would be required to extract the oil thus leading to a net loss of energy to the industrial society. Thus the continuation of industrialization as we have known would therefore depend entirely on the possibility of employing alternate sources of energy. This should also be the initial strategy of the developing countries.

Chapter 2

TECHNOLOGY AND THE ECONOMY IN THE UNDERDEVELOPED COUNTRIES

The large scale capital intensive technologies developed in Europe, North America or Japan may very well be "efficient" in some limited sense but their introduction into poorer less developed societies of the Third World raises both technological and moral questions. The newer problems created aggravate the existing economic difficulties. The capital intensive models are usually very costly relative to the income of the local populations, require an educational and industrial infrastructure which takes decades to build up, and their disruptive social consequences tend to be much more sudden than their culture of origin. But, even more destructive is the fact that their introduction often inhibits the growth of the indigenous innovative capabilities which are necessary if real development is to ever take place. The symbols of modernity in the form of steel mills, chemical plants, atomic reactors, and automobile factories can be purchased on the international market but development is a complex social process which depends to a great extent upon the internal innovative capabilities of a society. Imported ideas, values, norms, culture and technologies have a part to play but no society can develop exclusively on the basis of such imports. One of the crucial objectives of the developing countries should be to create, nurture and, more often, to rehabilitate the internal capacity to invent, improvise and innovate. Taking all these factors into consideration, the selectivity and choice of technology becomes very critical and the diffusion of methods and means of production are to be chosen so as to be best suited to local conditions.

2.1. Technology and its Effect on the Economy of the LDC's

The frustration felt by the developing countries with the transfer of technology from the industralised countries and the resulting disenchantment with the multinational corporations leads to the concept of appropriate technology for development. The technological approach to growth and development has resulted in grave social imbalances in the society and has initiated the dual economy in the Third World. In his book, Small is beautiful: Economics as if people mattered," E.F. Schumacher points to the unhealthy growth of the dual economy in the developing countries. This phenomena of economic growth has had an adverse effect on the distribution of wealth and employment and has resulted in bureaucratic corruption and political suppression. The social and political conflict arising out of an ideology which sustains the dual economy leads to the growth of two societies in the same country without a common goal. In the dual economy of a typical developing country, 10% to 15% of the population is confined to one or more urbanized cities with all the advantages of a modern society while the remaining 85% of the population which is made more primitive by the growth of the urban centers. The pattern of living and working among the elites in the cities are more or less similar to that of the developed countries while that of the rural areas are backward and are decaying and stagnating. As Hagen states:

> Everyone of these countries is a dual economy, set in the midst of a traditional agriculture and the processing of its products, minerals extraction and perhaps some processing of the ores, or the collecting and perhaps the processing of other natural resource products for export. These enterprises are run by foreigners and they are owned by foreigners except as they have recently been expropriated. The methods of production elsewhere are traditional. Those in agriculture are sometimes termed biblical. The wooden plough, planting seeds by hand, threshing by walking oxen around and around over the heads of grain- these are symbolic of the methods in use. Non-agricultural production is largely cottage industry: family sized enterprises versus traditional, capitalist versus precapitalist. The methods used in the modern enclave are so far removed from those that traditional producers could manage that there is little if any transfer of technology from the enclave outward, though there may be some training in skills. [1]

Much of the controversy concerning the means of providing technology to the developing countries centers on the nature and conditions of such provision and on the effect of these conditions on the recipient nations. The preference for capital intensive imported technology in the developing countries as opposed to the labor intensive domestic technology is based on the belief that such imported technologies are more efficient and reliable. At a time when most Third World countries are demanding more and more technology, decision makers have to clarify and bring some measure of coherence to their policy objectives. Most poor

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[1] E.E. Hagen, The Economics of Development, (Homewood, Illinois: Richard D. Irwin, Inc., 1968), p. 32.

countries advocate five basic goals for their technological policy:

1. to obtain the entire gamut of available technologies.
2. to optimize the use of those technologies within their societies in ways supportive of basic value options, development strategies and policy determinations in various sectors.
3. to create and disseminate as widely as possible a technological culture or mentality.
4. to build up the capacity to produce their own technology.
5. to have a fair pricing structure for their technological imports. 2.

2.2. Growth and Disadvantages of Dual economy

The other disadvantage of dual economy society is the distribution of income and material wealth. The economic class employed by the foreign technology-based industry in the enclaves is much better off both financially and physically in comparison to the citizens of the rural areas. Greater equality for the entire population of a country is rarely a priority goal set by development planners. It is praised rhetorically but in practice it is quite the opposite. The gap between policy rhetoric and reality in job creation and income distribution is revealed tragicomically according to the true story told by E.F. Schumacher:

> I was in a developing country not so long ago and was shown around a textile factory - the manager was a European, a very courteous man and he said he was proud to show me this factory because it was one of the most modern in the world. I said, before you go on can you tell me what's happening outside, because as I came through here there were armed guards there and you were beleaguered by hundreds and hundreds of Africans. Oh, he said take no notice of that, these are unemployed chaps and they

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[2]Denis Goulet, The Uncertain Promise, (New York: IDOC/ North America, 1977)

hope that I might sack somebody and give them the job. [3]

The obvious lesson is that the selection of technology by firm managers is dictated by many criteria, some of which have nothing to do with the minimization of costs or the creation of jobs. In order to have an equitable distribution of income, there has to be an intervention by the government which rarely happens. The economic elite employed by the imported technology of the enclave based industries, align themselves with the bureaucratic, political and military forces to protect their own interests and priveleges. The other major problem is the location of imported technology. Since the basic infrastructure, such as roads, railways, water supply, electricity, and banking and financial facilities are located only in the urban areas the imported capital intensive technology inevitably is sited there. This leads to the influx of unemployed and underemployed migrants from the rural areas leading to the further breakdown of the basic institutions of the cities. Absence of governmental social programs leads to the creation of slums, substandard housing, lack of potable water, medical facilities, schools, job training and ultimately is the cause of crime and political activism. They inevitably result in social disorders, health hazards, famines, political radicalization and suppression, and the denial of basic human rights and dignity.

2.3 Effect of Capital-Intensive Technology

Capital based imported technology comes in a package of

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[3] E.F. Schumacher, "Growth-Yes, but who for and how fast?," Encounter, vol. 9, no.4 (Geneva: World Council of Churches, 1973) p. 2.

management services which include training, production management, accounting, advertising, etc. Most of these are alein to traditional technology and consumers of the developing countries. In order to avoid large labor force along with an active labor union and artificially pegged rate of foreign exchange, the investor goes in for more capital intensive technology, which displaces more and more labor to join the unemployed ranks. To quote E.A.G. Robinson:

> 1. Industries in Bangladesh are more capital intensive than those in Japan. The only exception is the basic metals. This conclusion is further strengthened by the fact that even in Bangladesh cotton textiles industry for which a considerable amount of inter-country product similarity is believed to exist, the technology is more capital-intensive than that of the Japanese textiles.
> 2. Many of Bangladesh Industries are as capital-intensive as U.S. industries. What is more surprising is that capital intensity in the paper industry in Bangladesh exceeds the capital-intensity of the paper industry in the U.S.A. [4]

It is rather perplexing that in a country like Bangladesh with such a high level of unemployment, the industries have tended to be relatively capital intensive. This phenomena is quite prevalent in all the developing countries. Such lopsided developments which are detrimental to the society have created advocates who want to institute a moratorium on foreign technology and rather concentrate on the development of indigenous capability.

2.4 Ideology and Rise of the Multinational Corporation

Before gaining independence, the countries of the Third World,

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[4] E.A.G. Robinson & K. Griffin, The Economic Development of Bangladesh Within a Socialist Framework, ((London: The Macmillan Press Ltd. 1974) p. 249.

particularly of Asia and Africa which had been the colonies of the European powers, had already been penetrated with the infrastructures and technology of developed countries. The inherited technological installations became the immediate concern of the new Nation State when independence came. To man these they had to rely at the initial stage on the experts and technicians of the developed countries while indigenous administrators and technicians were being trained under a crash program. The newly trained and educated elites of the country became the most powerful supporters of the colonial developmental process which the country had inherited. By virtue of their own position they created demand for more and more capital intensive imported technology for their own vested interests.

Behind the whole range of goods and services demanded by the Third World Countries were the multinational corporations which had already made projections regarding market expansion in the developing countries based on newer consumers, expanding production and increasing growth and profit. The multinational corporation happens to be among several channels through which developing countries acquire technology from the industrialized Western World. However their role is the most important and controversial. The rise of the global corporations has been marked by two fundamental tenets of modern business faith: the cult of bigness and the science of centralization.

There is a curious correlation between the dismantling of colonialism and the rise of the multinational corporation. The vision of the global corporations is to own, manage and operate a world economy without regard to physical, political and cultural boundaries. The idea of treating the world as a global market and economy is in direct conflict with national strategies. The global managers are concerned more with the sources of raw materials, kind and cost of labor force, type of consumers and are unaware of the magnitude of world poverty. The central startegy of the global corporations is the creation of a global economic environment that will ensure stability, expansion and high profits. The implementation of the startegy depends upon the control of the three basic components of corporate power: finance, capital, technology and marketplace. Past record shows that multinational corporations have used these components of power to promote their own growth. These very strategies have had an adverse effect on the distribution of income and employment within developing countries along with bureaucratic corruption and political suppression. As J. Ramesh and C. Weiss Jr. puts it:

> Global interdependence is a fact of late 20th century life. We are all riders on Spaceship Earth- but alas a small portion of humanity travels first class and the rest are down in steerage. Melancholy evidence accumulates that the benefits of international cooperation for development flow unevenly both within and between countries. This is hardly surprising when the rules of the same game have been set by the more powerful actors in the international economic and political system. [5]

The ideology of the global corporation has its strongest supporters naturally, among the political, bureaucratic and military elite of

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[5] Jairam Ramesh & Charles Weiss Jr., Mobilizing Technology for World Development, (Praeger Publishers, 1979).

the developing countries who have their own vested interests. Underlying the irrelevance of most of the technological change to the social needs of the bulk of the population of the Third World countries is the unholy alliance between rich countries which collectively generate their own technology and the 10 to 20 percent of the population of poor countries who have adopted affluent-country consumption and tastes. The needs of the largely urbanized middle and upper income groups of the Third World can be served only by the imported technology from the countries of the West. The elites who control the strings of political and economic power in these countries have little incentive to break the links tying them to the technological development in advanced countries through investment, trade and other economic and political ties. According to Francis Stewart:

> To the extent that governments consists of individuals who benefit from and represent those who benefit from the political economy in being they may not wish or be able challenge it. An alternative technology at macrolevel involves an alternative political economy, a different distribution of the benefits of the economic system........ The effective pursuit of an alternative appropriate technology would threaten interests in the advanced countries who are currently benefitting from the use of advanced country technologies in developing countries. [6]

2.5 Multinational Corporation and the LDC's

The global corporation is the first institution in human history with the dedication to centralized planning on a global scale. They have the power along with the organization technology, money and ideology to try managing the world as an integrated unit.

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[6] Francis Stewart, Technology and Underdevelopment, (London: Macmillan, 1977.)

Since the primary purpose is to organize and integrate economic activity so as to achieve maximum profit, the global corporation is an organic structure where each individual component dispersed among the nation states in the world, goes on to serve the whole as represented by the corporate headquarters, from where the overall strategies are evolved and growth and profits are projected. The rise of the multinational corporation is a phenomena of post world war origin and the implications for modern man are as profound as the Industrial Revolution or the rise of the nation state itself. Their growth has been so spectacular that individual corporations have annual sales greater than the gross national products of many of the countries of the world.

The power of the global corporation derives from its unique capacity to use finance, technology and advanced marketing skills to integrate production on a worldwide scale. This cosmopolitan vision stands as a direct challenge to the traditional nationalism and, indeed, the nation state is the chief obstacle to planetary development with centralized control. According to William I. Spencer of the First National City Corporation with business in ninety countries, "the political boundaries of nation states are too narrow and constricted to define the scope and sweep of modern business." [7]

The symptoms of underdevelopment are easy to identify and have certain characteristics which are quite common to most of the

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[7] Richard J. Barnet & R.E.Muller, Global Reach, (Simon & Schuster, 1974), p.18.

developimg countries. It is often said that poor countries are poor because they lack capital stock and basic infrastructures and these shortcomings have prevented them from moving on to become modern developed societies. On the contrary, because power over material wealth was largely in the hands of the colonial rulers, the finance capital generated by past wealth producing activities has not been used for the development of these nations. It has been siphoned off to the developed world as plunder, dividends, royalties or technical fees. This transfer of capital from the underdeveloped to the developed world has been done in concert with the local elites, who have been left to enjoy the capital left behind in those countries at the expense of the majority of the populace. As Barnet & Muller put it:

> What a curious contradiction of rags to riches. One out of every ten thousand lives in a palace with high walls and gardens and a cadillac in the driveway. A few blocks away are hundreds sleeping in the street which they share with beggars, chewing gum hawkers, prostitutes and shoeshine boys. Around the corner tens of thousands are jammed into huts without electricity or plumbing. Outside the city most of the population scratches out a bare subsistence on small plots, many owned by the few who live behind the high walls. [8]

The industrialized nations, as the studies of Raul Prebish, Hans Singer and others has shown, have used their technological and marketing superiority to obtain terms of trade which not suprisingly favor them. Indeed the lack of power of the underdeveloped countries is due to three major institutional weaknessness. They are colonial and obsolete administrative

[8]Ibid., p.133.

structures where many of the laws controlling foreign business and collecting tax are inadequate. The second is the lack of strong labor movements, a condition which has allowed the global corporations to exploit cheap labor and play one faction against another. And the third major weakness is the lack of competition from indigenous businesses and entrepreneurs.

2.6 Transfer of Technology to the LDC's and its Consequences

Most underdeveloped countries have already made the decision to emulate the economics of the developed countries through a similar process of industrialization and, therefore, dependency on imported technology, finance capital, marketing techniques and especially the diffusion of the ideology of consumption which is built into the whole model of development. Once Western values and consumption have become primary goals of these nations they have to sacrifice the buildup of their own technological capacity for the quick boom of foreign investment. But the price one pays for that is quite obvious. A study by the United Nations showed that more than 89 percent of the patents in India, Turkey, Egypt, Pakistan are owned by foreign global firms. According to Fatemi and Williams:

> The transfer of technology by U.S. Companies produces real benefits for the United States in the form of net royalties and fees- $2.8 billion in 1972, 75 percent of which came from from U.S. affiliates abroad. Receipts have been expanding at a compounding annual rate of 12.8 percent since 1960. Payments of royalties and fees to foreigners are relatively small by comparison- less than $0.3 billion in 1972- yet their growth rate from 1960-1972 was 11.5 percent. [9]

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[9] Mary Frances Teplin, "U.S. International Transactions in Royalties and Fees: Their relationship to the transfer of technology," Survey of Current Business, Dec. 1973, p 14.

The multinational corporations are involved in the transfer of technology because it is an important source of invention and innovation. Being predominantly large firms, they have the resources for significant research and development efforts. Their affiliates worldwide absorb information about markets, costs, competition, and techniques, and transmit it to corporate headquarters where it is collected sorted out, stored, analysed and evaluated. Technology, defined as useful knowledge, is the very lifeblood of the multinational corporations. For this reason technology-related conflicts frequently involve high stakes for firms whether they be IBM, Coca-Cola, Westinghouse, ITT, Kennecott Copper on the one hand, or the developing countries on the other.

The transfer of technology by the multinational corporations to the developing countries has been at a great cost to those countries. The import of high technology invariably leads to a dual economy with varying social structures in those nations. For instance, the favoring of heavy industry leads to the relative neglect of other sectors of economy, particularly the agricultural. High technology is concentrated in areas that can provide modern infrastructures, which ultimately leads to development enclaves. Imported technology with virtually no localized research and development means the neglect of the locally research oriented graduates from the universities, who then emigrate and start the brain drain. The continual import of industrial technology from abroad has two important effects on the local economy. There is a shift in the balance of payment difficulties from import substitution to the payment of technology, and, secondly, there is an inbuilt bias towards a certain kind of growth inherent in competitive corporate technologies. Self sustained growth proclaimed by the planners of the underdeveloped countries becomes more and more elusive. As Robert Girling states:

> the transfer of technology has proved to be a subtle and pervasive mechanism in the preservation of structures of dependency in the Third World. 10

Technology sold by the multinational corporations favor growth with huge scale, high concentration and built in obsolenscence.

The creation of jobs and the reduction of unemployment which is common in the developing countries is an objective which has never been met. According to Jose Walter Bantista Vidal, Secretary for Technology in Brazil's Ministry of Industry and Commerce:

> the government does not expect to be able to reduce unemployment in the primary or secondary sectors but mainly in the tertiary (services) sector of the economy. 11

Development planners usually advocate industrialization and capital accumulation. Certain countries like India, Brazil and Iran have aspired to become regional powers and as such have followed a certain strategy to that effect. India is trying to achieve an autonomous nuclear capability and Brazil an infrastructure to produce sophisticated weapons. This has been done at a great cost to the overall development of the economy. Iran on the

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[10] Robert Girling, "Dependency, Technology and Development," Structures of Dependency, (California: Stanford University Press, 1973.) p. 46.

11 Denis Goulet, The Uncertain Promise, (New York: IDOC/North America, 1977.) p. 125.

other hand under the Shah signed an agreement for orbiting satellites to provide television and telephone connections to the 20,000 villages of Iran under the pretext of educational purposes. Since the villagers were too poor to afford their own television sets it could only be used for propaganda or survelllance by the secret police.

2.7 Development Strategy for the LDC's: Towards a New Model.

A development strategy should stress the three elements of social justice: equality, equity and participation. Unfortunately technology transfer has led to the benefit of few priveleged professionals. According to a study by Adelman & Morris:

> greater inequality of income distribution and increasing concentration of wealth in the hands of the priveleged few occur in the first years of economic development. [12]

The application of appropriate or inappropriate technology has become an issue of concern in the developing countries. An interesting study by Harvard professor J.W.Thomas on technological alternatives for Bangladesh is a case in point. In the 1960's, for example, external financing was available for implanting irrigation tubewells, and though detailed cost analysis were made for several types of tubewells, the capital intensive option was selected.

> On balance the arguments for the low-cost wells over medium and high cost, appear impressive. With low cost wells, economic return is higher, the employment and training

[12] I. Adelman & C.T.Morris, "An Anatomy of Income Distribution Patterns in Developing Nations", Economic Staff Paper no. 116, (Washington D.C. : International Bank for Reconstruction & Development, 1971.)

> effects are greater, the components of the wells hold greater potential for the creation of domestic industry and they will provide a broader distribution of the benefits of well-irrigation................ The fact that the Government requested assistance primarily for medium and high cost wells suggests that standards other than those examined are paramount in the decisions of Governments and aid-givers as the appropriate technologies of developing countries. 13

The culture of any society expresses itself in the modes of work it chooses and in the means by which it relates work to leisure. Cultural autonomy is difficult to maintain in conditions of rapid change and homogenization. Consequently, standardization becomes an all pervasive phenomena. Modern technology once transferred to matrices other than those of its origin, imposes its logic and uniformity on tools, work paces, and safety regulations. Nowhere do the values of modern technology so quickly assert their primacy or win converts as rapidly as in the behaviour of business and professional elites. Indeed technology transfers impose a very high price in cultural dependency, a price which can be minimised by deliberate policy measures only if cultural homogenization is recognized as a serious danger inherent in umcritical technology transfer. Technology transfers between rich and poor countries as presently conducted result in very social and human prices in the receiving societies. Most of these costs are not readily measurable and often not easily detected, but are, nonetheless, real. Most important of all, they are not inevitable and this leads to the

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13 Denis Goulet, The Uncertain Promise, (New York: IDOC/ North America, 1977) p. 131.

arguments of the appropriate technology movement. Because the costs are high, Third World societies should not uncritically receive technology from the developed world but strive to create technologies in harmony with the values they cherish. Once they achieve this they will strengthen their capacity to receive foreign technologies in a more creative and less destructive fashion.

Chapter 3

APPROPRIATE TECHNOLOGY

Development as we know it today is hardly possible without technology. Moreover, the technological level necessary for the attainment of any delineated developmental goal is more easily reached when there are relevant developments in science. Technology is, in most cases, a product of some sort of science. The driving force behind the industrial growth and the widespread use of technology in the developed countries of the Western World has been based on the expansion of scientific knowledge. Modern technology developed when natural resources were abundant and human labor was relatively scarce and expensive. With the shrinking of natural resources, worldwide unemployment is increasing and other economic problems are growing, a condition that will soon force the industrial world to adapt its technology to the new conditions. This is one of the major underlying reason for the appropriate technology movement.

3.1 Origins and Meaning of Appropriate Technology

The quest for environmentally appropriate technologies is the result of an evolutionary process that began in the 1960's. The preceding post war years were marked by rapid industrial expansion and unprecedented public confidence in the ability of modern technology to provide us with both abundance and happiness. However , in the mid

1960's a reaction developed particularly amongst Western youth and intelligenstia against competitive, high consumption, high technological society. This shift in values coincided with the emergence of a school of thought first put forward by Rachel Carson in her book "Silent Spring"and followed by people such as Illich, Lovins, Commoner, Schumacher and others. Their argument was that high technology and rapid economic growth based on fossil fuels and finite resources were destroying the environment and causing disruptions of the biosphere. They also said that mankind like all organisms on this planet, depend on a healthy biosphere for their existence. David Dickson states it as such:-

> To many, advanced technology appears to be the prime cause of our present environmental problems. This case is argued strongly by Prof. Commoner in his book "The Closing Circle". Commoner claims that the levels of different pollutants in the United States rose by between 200 and 2000 percent from 1946 to 1971 and that neither increasing population, nor a rise in the general standard of living,were sufficent to account for the most excessive of these increases .... Commoner claims that synthetic fibres increased by 5980 percent;mercury used for chlorine production increased by 3930 percent, the production of air compressor units by 2850 percent, plastics by 1960 percent, synthetic organic chemicals by 950 percent and elctric power by 530 percent. [1]

This school of thought spawned the environmental movement, a widespread public awareness of the importance of the natural environment which led to a movement to clean up industry, automobiles, and waste disposal system. It has been agreed among environmentalists that even if advanced technology is not the only culprit, it must nevertheless share a large part of the blame for the extent to which

[1] David Dickson, The Politics of Alternative Technology, (New York: Universe Books, 1975), p.19.

man has polluted the natural environment and used up the world's resources. The intellectual catylst who outlined the basic concept of the environmental movement came from the book, Small is Beautiful: Economics as if people mattered, by the English economist E.F.Schumacher. His argument was that intermediate technology which would employ more people and be more benign and sensitive to the environment would serve society better than machines which enslave the people who use them, rather then empower them.

3.2 Semantics of Appropriate Technology

As such, the selectivity and choice of technology becomes very critical and the diffusion of methods and means of production are to be chosen so as to be best suited to local conditions. Technologies which meet this criteria have been described as "appropriate","low-cost","intermediate", "alternative"and so on. The ambiguities and differences between the varoius types of alternative technologies are so fine that they overlap each other. The term implies the use of indigineous materials and minimal use of non renewable resources such as fossil fuels. As defined by the U.S. Agency for International Development, "appropriate technologies are intensive in the use of labor, economical in the use of capital and trained personnel and intensive in the use of domestically produced inputs." [2]

A technology is only appropriate or inappropriate by reference to criteria or objectives which are themselves specified in empirical

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[2] United States Agency for International Development, Proposal for a Program in Appropriate Technology, rev. ed. (Washington,D.C. :U.S. Government Printing Office, 1977.)

terms. The ox-plough introduced in tropical African countries is a good example of an intermediate technology. It lies somewhere between the traditional hand operated hoe and the modern diesel tractor.

> Intermediate is however relative, because in the Asian societies which have had ox drawn ploughs for thousands of years, such technology is traditional and, in this case, the intermediate would be the small two wheel tractor of the type developed by the International Rice Research Institute. [3]

In the tropical African societies which do not have the tradition of livestock breeding, the ox-drawn plough is a major technological innovation. In appropriate technology the economic viability of new technology is important but it is more imperative that it can adapt to the local social and cultural environment. The appropriateness depends on the value judgement of the proponents of the system. On the other hand the criticism of modern technology emanates from an ideological belief which ties together diverse goals and objectives of innumerous variables.

The radical departure from this philosophy by the advocates of "appropriate, intermediate, soft" technology has been confusing at times, particularly because of the loose defination of the various concepts and the overlapping and the interchangeability of the terms. In spite of these criticisms, the various concepts are nevertheless distinct areas though the lines of demarcation can at times become fuzzy. They are therefore best identified in terms of the communities that formulate and practice them. Appropriate technology

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[3] A.U.Khan, "Mechanization Technology for Tropical Agriculture", Appropriate Technology Problems and Promises, ed. N. Jequier, (Paris: Development Center of the Organization for Economic Co-operation and Development, 1976.)

is really an umbrella which covers a whole host of alternative gadgets, materials, skills, processes, principles and philosophies. All these groups are striving to create technologies which satisfy directly human needs other than through sheer productivity through the profit system.

> Each group has a different primary focus, emphasizing, for example, the following: workers control, low specialization, demystification of expertise, reform of the worker role, local or regional self sufficiency, balanced economic development under low capital, environmental stability. 4

As Harper & Erickson state in their Alternative Technology Guide:

> It is hard to claim that all these add up to a coherent program but they all seem to us to be groping in roughly the right direction, all tending to go against the modern thrust to increase the power and sophistication of technology as if for its own sake irrespective of other human goals. 5

All the groups see that the growth and expansion of modern industrial societies is interrelated with the high consumption and high productivity motive of capitalistic economies, and as such that the real blame lies in unrestricted expansion of capital-intensive industrial technology. Schumacher expresses his criticism in more humanistic and ethical terms. According to him the fateful error of our age is that the modern industrial system consumes the very basis on which it is erected. It is sustained by irreplaceable capital in the form of fossil fuels and the tolerance margin of nature and human resources. He proposes the following criteria for methods

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[4] H.Herring, Alternative Technology, (Brighton : Smoothie Publications.)

[5] Harper and Erickson, Alternative Technology Guide, 1972.

and equipment which will reverse the destructive trends now threatening industrial societies. Technology should be:

1. Cheap enough so that it is accessible to virtually everyone.
2. Suitable for small scale application.
3. Compatible with man's need for creativity.

3.3 Concepts and Criteria

E.F. Schumacher, who first advocated the concept of appropriate technology, states that the criteria of achievement by modern man is measured by money. The development of production and acquisition of wealth is the objective of the modern world and everything else is secondary.

> We shrink back from the truth if we believe that the destructive forces of the modern world can be brought under control simply by mobilizing more resources: of wealth, education and research to fight pollution, preserve wildlife, discover new sources of energy and to arrive to more rational coexistence. What is most needed by society is the revision of the ends which these means are to serve. This implies above else, development of a life style which accords to material things their proper, legitimate place, which is secondary and not primary. [6]

Arguments regarding the concept of appropriate technology relate to the utility of technology and to the feasibility of its application. Barry Commoner emphasizes the use of natural products to offset the negative ecological impacts of man's use of synthetics. The characteristics of appropriate technology as visualized by Schumacher is the application and the correct choice of technology critical to the local situation. In order to improve the quality of life and environment the most appropriate technologies are most

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[6] E.F. Schumacher, Small is Beautiful: Economics as if people mattered, (New York: Harper and Row, 1973.) p. 272.

often intermediate technologies. According to Congressman Clarence Long the concept of appropriate technology can be explained as follows:

1. It is not primitive or obsolete but economic, culturally congenial and ingenious in design.

2. It should represent the least-cost solution taking into account the factor costs of production.

3. Labor intensiveness is a necessary condition.

4. It is a low capital investment enterprise.

Appropriate technology, on the other hand, is conceived as rooted in economic reality and the basic needs of the people for income and employment. It is relevant to the plans and programs of the LDC's as its objective is to tackle the multifaceted problems of those countries, while it makes the optimum use of the existing resources of a given country. A major criteria for the choice of appropriate technology is not the usual western productivity measure of output per worker but rather output per unit cost of the inputs of capital and labor. According to Ken Darrow:

> this technology is especially attractive because it seems to solve a number of problems at once. Because it involves self reliance and local production for local needs on a national level this approach can remove from the list of obstacles to development many of the inequities of an international system that is dominated by the expensive technology and economic power of the rich countries. At the same time the lack of well developed infrastructure and the shortage of highly trained manpower to run large industrial operations becomes much less important when people are allowed and encouraged to develop themselves. A whole array of problems can be potentially be solved at once. [7]

[7] Ken Darrow & Rich Pam, Appropriate Technology Source Book, VITA, (Stanford: CA. 1978.)

3.4 Appropriate Technology as a Tool for Development

Accordingly appropriate technology may **best be seen as a** humanistic movement aimed at counter balancing the mechanistic view of the world that has prevailed since the industrial revolution. The term refers to specific lists of tools or techniques which have the following characteristics:

1. Low in capital costs.
2. Use local materials whenever possible.
3. Create jobs employing local skills and labor.
4. Are small enough in scale to be affordable by small **farmers.**
5. Can be understood, controlled and maintained by villagers.
6. Can be produced out of a small metal working shop if not in a village itself.
7. Suppose that people can and will work together collectively to bring improvements to the communities recognizing that in most communities societies important decisions are made by groups than individuals.
8. Involve decentralised renewable resources such as wind power, solar energy, water power, methane gas, animal power and pedal power.
9. Make technology understandable to the people who are using it and can be intrumental in further innovations.
10. Are flexible enough so that they can be adapted or used to fit changing circumstances.
11. Do not involve patents, royalties, fees, import duties, shipping charges or financial and management wizards.

Appropriate technology as a tool for development, stimulates production in rural areas and can create many spin off benefits. Firstly the rate of world starvation particularly in the underdeveloped LDC's may be diminished. In addition, increased agricultural productivity at the individual level may break the widespread dependence on subsistence farming.
Appropriate technology increases rural employment and utilizes the surplus labor which is common to all rural agricultural societies of the LDC's. It cuts down and limits the flow of migratory movement of rural residents to the urban centers. Increased employment in the rural areas **helps** create a better distribution of wealth and leads to other development activities in **those** region. More individuals participate in the development process of a community, which leads to a decrease in alienation. Innovation, a basic factor of appropriate technology, help to eliminate the element of drudgery, which is quite common in large scale technology.

The smallness of appropriate technology result in less disruption of existing social and ecological systems. Because local resources, tools, and technologies are the major factors of appropriate technology, it generates other localised industries with a demand at the local level. Appropriate technology has the advantage of reducing the dependence of the LDC's on industrialized nations by increasing self reliance and reducing inequalities.

3.5 Criticism and limits to appropriate technology

The appropriate technology approach has been criticized for a variety of reasons. One of the major criticism is that this form of technology is an instrument for keeping the LDC's from acquiring modern technology and rapid development. It is quite obvious that appropriate technology stresses more labor intensive localized technologies rather, than capital intensive as a strategy for development for the rural poor of the LDC's. To the unemployed rural poor, the form of technology is irrelevant since the issue of job opportunities is the prime need. Appropriate technology does not simply imply the use of second hand obsolete technology, but it stresses the use of adaptable technology which offers the best solution to a community at a given time. It is not out to replace modern technology but is an approach for more integrated development process. Another major criticism has been that appropriate technology keeps the developing countries from world markets which monopolize energy and raw material resources. On the contrary, it makes better sense for LDC's which have scarce foreign exchange for competing for increasingly scarce and costly non-renewable resources in the world market. It is clear that survival with dignity means more reliance on renewable resources for their development.

According to D.D. Evans and L.N. Adler there are certain barriers to appropriate technology. They have been categorised as:

1. Efficiency of Capital Utilization:
The artificially low cost of capital in LDC's encourages the use of capital-intensive technology over labor-intensive at the initial stage. Capital intensive industry is more efficient and generates more secondary industrial requirements and has a multiplier effect in the economy.

2. Aspects of Labor Utilization and Development:
In LDC's labor is less dependable, skilled management is in short supply and to maximize output and create efficient industry, capital intensive technology is preferred.
3. Market Considerations:
Labor intensive technology along with the absence of skill, leads to sub-quality products which have limited acceptance and cannot compete in the export market.
4. Logistical Considerations:
Decentralised, dispersed manufacturing sites, along with inadequate transportation networks, create ineffeciency, cost inefficiency, cost overruns, and limited markets.
5. Technological Considerations:
Technology from industrialised countries are more readily available, more dependable, and invariably more expensive. Besides, modern capital-intensive technology may be required for the future industrialization of the LDC's to broaden the economic base of those countries.
6. Governmental Policy Effects:
Often governmental policies are inconsistent in the adoption and use of technology.
7. Public Attitudes:
There is a feeling that appropriate technology is "second hand" "second best," "obsolete," etc. and is designed to keep the LDC's backward." 8

The idea of innovation and improvisation is central to the appropriate technology movement. But one of the major weaknesses of the LDC's is the lack of basic research in the scientific field. Developing countries by and large do not over invest in basic research, and as such there is no local capacity to absorb technology. As Charles Weiss Jr. states :

> Yet basic research on a modest scale is a good investment for developing countries. It is a relatively inexpensive way to keep good university faculty in the country who are

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[8] D.D. Evans & L.N. Adler, Appropriate Technology for Development, (Boulder: Co. Westview Press, 1979.)

> in touch with world trends in technology, intelectually alive, and turning out well trained students." 9

Ideally, basic research in LDC's should be organised around a local problem that is both scientifically challenging and of major importance. For example, it can be wildlife ecology, parasitology, solar energy,nitrogen fixation , properties of tropical flora and fauna. But since one of the major difficulties in the LDC's, is the lack of long term financial support, international scientific collaboration is a must.

3.6 Development of Appropriate technology

According to Ross Hammond, the following criteria are essential for the research and development of appropriate technology:

1. Problem and need identification: The selection of appropriate technology must be preceded by a recognition of a problem or need.
2. Available alternative technologies and resources: Some determination of the technologies which are known and available must be made in the light of available materials and resources.
3. Analysis of the alternative technology: must consider educational, social, cultural, economic and infrastructure available to solve a problem.
4. Design and adaptation: Technology from the developed world should be adapted or redesigned when applying to the developing countries.
5. Prototype development: Prior to adaptation of any imported technology, a prototype should be built to analyse its operating

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[9] Charles Weiss, Jr. "Mobilizing Technology for Developing Countries", Science, vol. 203, 16 March, 1979, p. 1088.

characteristics and performance.

6. Testing, evaluation and modifications: The prototype must be subjected to testing and evaluation and modification should be incorporated if necessary.

7. Replication of innovation : If the prototype is commercially feasible, manufacture should be done to supply the market needs.

3.7 Recommendation for Appropriate technology application :

For the application of appropriate technology, Eckhaus recommends that an industrial technology inventory be taken of each country as a preliminary to planning. The elements of the policy formulation and planning function are:

a. Do adequate research to become knowledgeable of as much of the background of the country's external and internal environment as is required and feasible.

b. Ascertain the national development goals and objectives both tacit and explict.

c. Develop a plan for technology utilization that is consistent with factor endowments, national objectives and political constraints.

In conclusion, it is the conviction of the developing countries, that technology is a key element of development, but that it is outside their control because the world system of science and technology does not work in their interest. Technology meets the demands of market, and in the LDC's it meets the needs of the well off and not those of the poor.

If the innovation system is to work on behalf of the developing countries, one has to devise alternatives to the global industrial market in order to promote innovation in areas where there is a need but not a demand. The analysis of appropriate technology leads to reasonable optimism as to what can be achieved by policy actions, both internal and external. The concept is multidimensional and any search for simplistic or emotional solutions is likely to mislead and cause confusion. Neither the return to Gandhian handicrafts nor the search for the big technology breakthrough is the panacea for the under developed nations. The latest technology is not invariably inappropriate nor is the most basic technology invariably appropriate. A capital intensive technology may be the most efficient, and the average citizen may not buy appropriate technology. Appropriate technology does not offer an absolute prescription but rather a process of choosing from among a broad range of options. It seeks to optimize solutions whenever possible through reliance on problem solving capabilities of local people along with the sensitivity to environmental and cultural impacts.

Chapter 4

SOLAR ENERGY

4.1 LDC's and Energy Requirement for Economic Development

The future well being of any society is interrelated with the production and consumption of energy. With the ever increasing global demand for energy we are going to face conflict over energy shortages and a detrimental level of pollution and land desecration from the exploitation of fossil fuel. Fossil fuels as they have been used so far, are very inefficient. Five-sixths of the energy used in transportation, two-thirds of the fuel burned to generate electricity, and almost one-third of all the remaining energy usage is discarded as waste heat. That is more than half of the total energy consumed by any society. Moreover a good part of the fuel is emitted as polluting compounds like carbon, sulpher dioxide and nitrous oxide. In trying to raise the living standard of the Lesser Developed Countries (LDC's :see appendix A), the major barrier is the availability of energy resources.

> According to the present statistics, the advanced countries, with 31.4 percent of the world population, consume 84 percent of the world energy. Besides, it is estimated by the year 2000, the same group of nations with 27 percent of the global population would consume 68.4 percent of the energy........ LDC's with 19.7 percent of the people have one percent of the energy and by the year 2000 with 22 percent of the population would have 2.3 percent of the energy. [1]

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[1] J.C.Kapur, "Socio-economic consideration in the utilization of Solar Energy in underdeveloped areas", Solar Energy, vol.6, #3, 1962.

According to the present growth rate, it is estimated that by the year 2000, the world population will grow to six billion and the per capita energy usage would rise from 1.16 equivalent tons of coal to 2.62 tons. Therefore by the time the LDC's have succeeded in building up an industrial complex around the existing sources of energy the fossil fuel resources might reach the stage of near depletion.

Another important factor is the distribution of population and the demand for energy in the LDC's. According to the United Nations estimate in 1970, the rural population fromed approximately 75 percent of the total population of the LDC's, which was 1.89 billion. The estimated figure for the year 2000 would be 2.92 billion or 59.2 percent. At present the energy requirement in the rural areas is low and consumption needs are met by locally available firewood, charcoal, animal and human waste. The program of rural electrification is tremendously expensive and slow because it is capital intensive, and involves the connection of dispersed and remote villages to an integrated network. For instance, Bangladesh has over 65,000 villages with nearly 80 million people dispersed over an area of 56,000 square miles. Thus there is a need for developing decentralized energy systems for the rural areas of the LDC's.

4.2 LDC's and Renewable Energy Resources (Appendix- B)

Most of the developing countries are poor in conventional fossil fuel resources and have to import them. As such they have to rely on renewable forms of energy. All renewable energy resources trace back to the sun, and are replenished seasonally by nature. Solar radiation, wind energy, biomass, hydroelectric power are some of the sources available to the LDC's. The most important consideration in the use of solar energy is that it is the greatest source of energy, which is not only inexhaustible, but available all over the globe. Developing countries are well endowed with one or more of the renewable resources and in many instances they can be utilized with intermediate technology and the human resources available. In the context of most of the underdeveloped countries, solar energy has always been more a part of life than any other source of energy. The problem is how to more efficiently tap this renewable resource.

The lesser developed nations may enter the solar age much before the industrial world does. Several factors support such a belief including the fact that the developing nations are richly endowed with sunlight because of their location on the globe; their populations tend to be dispersed enough to facilitate the exploitation of decentralized energy resources. About half the people in latin America, seventy percent in South Asia, and eighty five percent in Africa are rural dwellers. As Denis Hayes states:

> Rather than using tax breaks as incentives to encourage foreign interests to set up automobile plants on their soil, Third world countries might, for example, accept only only those factories that produce vehicles that run on fuels other than oil. Rather than devote large portions of their budget to investments in highways, they might better invest in communication systems and railroads. Rather than laying out huge new cities to accomodate migrants fleeing the countryside they might do well to spend the same money making rural villages more livable.[2]

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[2] Denis Hayes, Third World Options, (World Watch Paper 15 Dec, 1977.)

Solar technologies hold many attractions for developing countries. A major social advantage is the potential for promoting develop development in previously ignored rural areas. Many of the solar technologies will make economic sense for the LDC's, before they can do to the industrialized countries. Electricity produced from solar energy is a good case in point. In the rural areas of poor countries, where no transmission and distribution infrastructure exists, power from centralized plants is not available. According to the World Bank estimates the rural electrification programs had reached only 12 percent of the people in the rural areas of the Third World by 1971 and only half of them could afford to buy power. One of the major criteria for development is the creation of new jobs. According to Denis Hayes:

> One liter of gasoline burned in one horsepower engine will provide as much work as a human being can produce in seven days of hard physical labor. Gasoline derived power is not only cheaper but also faster and more reliable than muscle power. Hence the point is sometimes made that major increases in Third World energy use may contribute to mounting unemployment. [3]

On the contrary if full employment is pursued intelligently, energy growth can increase rather than restrict total employment. As Arjun Makhijani and Alan Poole have suggested:

> The careful mechanization of plowing and harvesting could reduce the duration of these bottlenecks sufficiently to allow multiple cropping. Demand for labor would be evened out, agricultural production would be greatly increased and jobs could be created to handle increased production, as well as the fertilizer and irrigation it would require. Without an increase in the available energy at times of

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[3] Denis Hayes, Energy for Development: Third World Options, (World Watch Paper 15, Dec. 1977.)

peak demand for work, multiple cropping would not be possible. 4 The energy crisis of the LDC's dwarfs the energy problems of the industrialized world. Traditional sources like firewood, charcoal are growing scarce and expensive. Where the ecological balance of nature has been disturbed, deforestation has occured, with the forests and grasslands receding and the desserts increasing.

4.3 LDC's & Nuclear Energy

Because of the lack of fossil fuel reserves in the LDC's, the use of nuclear power has been strongly urged upon them. However as of late, notwithstanding the tremendous risks of nuclear power, the reserves of uranium the basic fuel for nuclear power reactor are being depleted so fast that it will barely last into the 21st century.

> Most Third World countries would also have to turn abroad for fuel because uranium is no more evenly distributed on the globe than oil, coal , or gas. Just four nations, the United Sates, Canada, Australia and South Africa possess 85 percent of the entire noncommunist uranium reserves. Australia has stopped exporting uranium while Canada and the United States have limited their exports for political reasons." 5.

Besides, nuclear power is just about limited to the generation of electricity only, and as they operate now, fission plants are less efficient in primary energy conversion than conventional fossil fuel plants. In addition, twice as much water is

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[4] Arjun Makhijani & Alan Poole, Energy & Agriculture in the Third World, (Cambridge: Mass. Ballinger Publishing Company,1975.)

[5] Denis Hayes, Nuclear Power: The fifth Horseman, ((Washington D.C.,: World Watch Institute, May 1976.)

needed to cool nuclear plants than fossil fuel plants because of the intense heat they create during operation.

> An important constraint to the applicability of nuclear technology to the LDC's is imposed by the need for overall system design. Interconnected electrical grids must be capable of continued operations even if their largest single power source fails.......large U.S. reactors achieved average capacity factors of only 51 percent versus the 70 to 80 percent predicted by the nuclear industry. At least 6000 to 10000 megawatts of installed capacity are needed to accomodate a single 600 megawatts reactor if power is to be shut down. By this criterion, only five Third World countries are in a position to accomodate securely even one small reactor. [6]

4.4 Advocacy for Solar Energy

"About one-fifth of all energy used around the world now comes from solar resources: wind power, bio-mass and direct sunlight." [7] Different solar sources will see their fullest exploitation in different regions. Wind power potential is greatest in the temperate zones while bio-mass has the best possibility in the tropics. Direct sunlight is most intense in the cloudless desert while waterpower depends upon mountain rains. Solar energy is the most abundant form of energy available and it has indirectly been the source of the fossil energy stored in the earth's crust. The existing energy resources are being depleted so fast that it is probable that nearly 40 percent of the global future energy requirement can be provided from solar sources by the year 2000. The sun

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[6] Richard J. Barber Associates, Inc., LDC Nuclear Power Prospects, 1975-1990: Commercial, Economic & Security Implications, (Springfield; Va., National Technical Inform. Service, 1975.)

[7] Denis Hayes, Energy: The Solar Prospect, (Washington, D.C.: World Watch PaperII, March 1977.) p. 5.

is a thermal reactor with high temperature because nuclear fusion of hydrogen isotopes are constantly taking place inside it. The surface temperature of the sun is 6000K, while the solar constant which is the radiation density incident at the outer edge of the atmosphere of the earth is on the average 1.4 Kw/m^2 . The sun's major energy output is in the form of electromagnetic radiation and the estimated power radiated from it is $3.8x10^{26}$ watts of which $1.7x10^{17}$ watts is intercepted by the earth. "The amount of solar energy reaching the earth annually is 28,000 times greater than all the energy used by mankind."[8] (See appendix C)

Generally speaking the greatest amount of solar energy is found in two broad bands around the earth between the 15^o and 35^o north and south parallels. In the most favorable regions between these parallels there is a minimum monthly radiation of 500 $cal/cm^2/day$. These regions are on the equatorial side of the world's arid deserts. They have less than 25 cm of rain in a year. In some countries in those regions more than two thirds of the area is arid and there is usually over 3000 hours of sunshine per year. The next most favorable region for the purpose of solar energy application is in the equatorial belt between the 15^oS and 15^oN parallels. There the humidity is high, cloud cover is frequent and the proportion of scattered radiation is high. There are about 2500 hours of sunshine

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[8] Ibid p. 8

per year with very little seasonal variation. Radiation is from 300 to 500 cal/cm^2/day throughout the year. Between the 35^o and 45^o parallels at the edge of the desert areas the radiation can average 400 to 500 cal/cm^2/day on a horizontal surface throughout the year, but there is a marked seasonal effect and the winter month's have low solar radiation. The regions beyond latitudes 45^o N and 45^o S are limited in their year round use of direct solar energy. Most developing countries are located between 35^o N and 35^o S and these are the regions on the globe which are most blessed with sunshine(Fig. 1). The relative high population densities in the rural areas in these regions and the high exposure to the sun make it natural for the application of solar energy, which lends itself to decentralized power plants of small size. This form of energy therefore, should be given higher priority.

4.5 Types and Application of Solar Energy

Direct utilization of solar energy will be of two categories, a decentralized small scale and immediate category and a centralized large scale and future oriented one. The immediate applications of solar energy will be water and space heating, air conditioning of houses, schools, shopping centers, offices. Future-oriented applications will be large scale thermoelectric and thermoionic conversion, photo voltaic and photochemical conversion, large scale sea water distillation and solar furnaces.

The following solar technologies have been selected because they are in use in various parts of the world today. The equipment are commercially available but with further development

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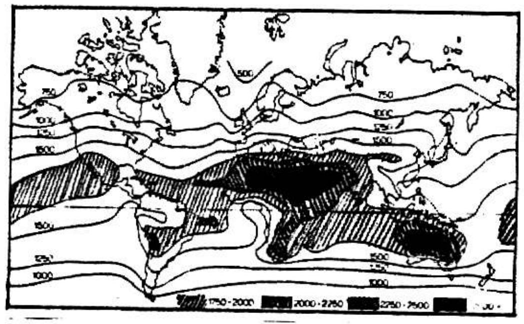
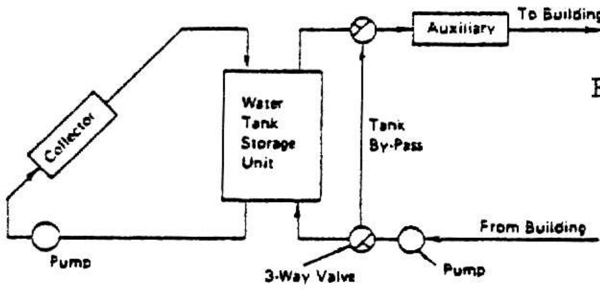
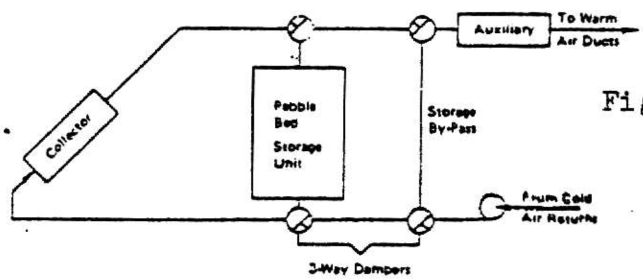


Fig. 1 shows total mean annual global radiation over the globe in kWh/m^2.



Schematic of basic hot water system.
[Courtesy John Wiley & Sons, Inc.]

Fig. 2 shows solar space heating where water is the medium.(schematic)



Schematic of basic hot air system. †Courtesy John Wiley & Sons, Inc.]

Fig. 3 shows solar space heating where air is the medium. (schematic)

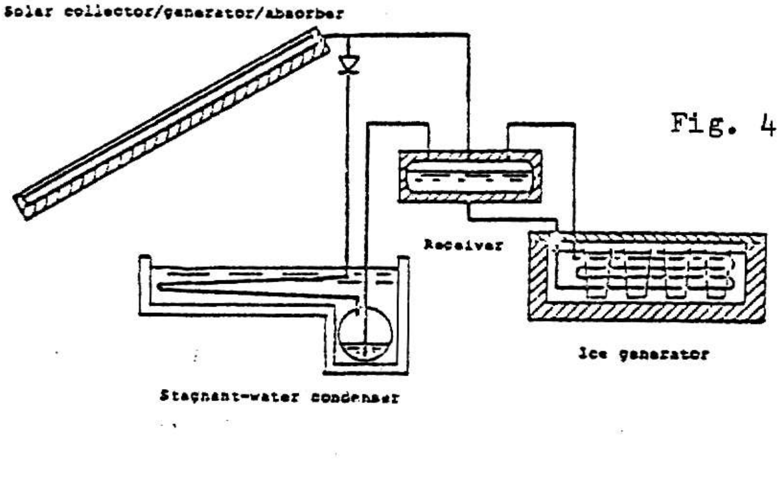


Fig. 4 shows an intermittent solar absorption refrigerator.

the technology can be expected to be adopted in the LDC's.

1. Heating of water for domestic and commercial use.
2. Heating of buildings
3. Cooling of buildings
4. Drying of agricultural and animal production
5. Salt production by evaporation of sea water or inland brines.

The indirect uses of solar energy have been the exploitation of

1. Wind energy
2. Hydro power
3. Photosynthesis
4. Microbiological conversion of plant materials to liquid fuels. [9]

The heating of residences in most developing countries is not a primary problem, though in certain regions it would help to improve the living conditions. Traditional architecture have evolved in the LDC's, taking into consideration the orientation to the sun, cross ventilation, use of materials for the retaining of heat. The technology of solar space heating where water is the medium is really an extension of the technology used in solar water heating, except that energy has to be recovered from the tank through a heat exchange surface (Fig. 2). Systems which employ air as the medium for heat transfer between the collector and a storage bin containing small rocks are quite successful (Fig.3).

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[9] Board on Science and Technology for International Development, Energy for Rural Development: Renewable Resources and Alternative Technologies for Developing Countries (Washington,D.C.: National Academy of Sciences, 1976).

Solar heat which is stored in the rocks are recovered by the passage of air over them when necessary. A feasibility study of solar heating for Iran has been found it to be economically practical for that country.[10] Solar energy can be accomplished by converting solar power to a mechanical form so as to operate a compressor. In order to cut down the high cost due to the conversion, an absorption refrigeration cycle can be used. In that process the pressure of the refrigerant vapor is raised by heating instead of by mechanical compression. The vaporized refrigerant is recovered for recycling by absorption in a solution of the refrigerant and salt. The low pressure of the expansion/vaporization region is maintained by the reduced vapor pressure of the refrigerant above the absorbent solution and the vapor is regenerated by allowing the solution of refrigerant and absorption to flow into the generator where solar heat is applied. It is particularly important to note that solar air conditioning uses the same collector and storage system for cooling as for winter heating. In the LDC's, solar air conditioning can be utilized by residences, community buildings, factories and offices.

4.6 Potential Renewable Resources

In many tropical and developing countries, a substantial quantity of foodstuffs cannot be preserved and therefore perish. For some foods, refrigeration is necessary, while for others solar drying is vital and as such in rural areas without

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[10] Mehdi N. Bahadori, "A feasibility Study of Solar Heating in Iran", Solar Energy, 15:3-124, 1973.

electricity, solar power is needed. Solar energy can be used to operate a heat engine which in turn can power a compression type refrigeration. But the simplist and cheapest way would be by using the sun directly in an intermittent absorption-desorption cycle for the purpose.

4.6.1 Solar Refrigeration: Figure 4 shows a schematic representation of an intermittent solar absorption refrigerator. This process utilizes the solar cycle and would be most useful when applied on a communal basis in the rural areas. A communal solar refrigeration plant could be a cold storage plant for the preservation of food stuffs, and medical and biological materials. The working substance for the absorption system for the plant could be any of the following absorbent/refrigerant combinations.

1. Lithium bromide/water (Li Br/H_2O)
2. Water/ammonia (H_2O/NH_3)
3. Sodium thiocyanate/ammonia ($NaSCN/NH_3$)
4. Lithium nitrate/ammonia ($LiNO_3/NH_3$)
5. Calcium chloride/ammonia ($CaCl_2/NH_3$)
6. Stronthium chloride/ammonia ($Sr\ Cl_2/NH_3$)

Some of the above refrigerants are liquid and others solid. The liquid absorbent and solid absorbent refrigerant have their own advantages and disadvantages. Solar refrigeration is normally more expensive than the other conventional methods, but in rural and remote areas of the LDC's, it is a good alternative.

4.6.2 Solar Water Distillation: Solar water distillation is most relevant to the arid zones of the world where insolation levels are high. The technology is basically of two types:

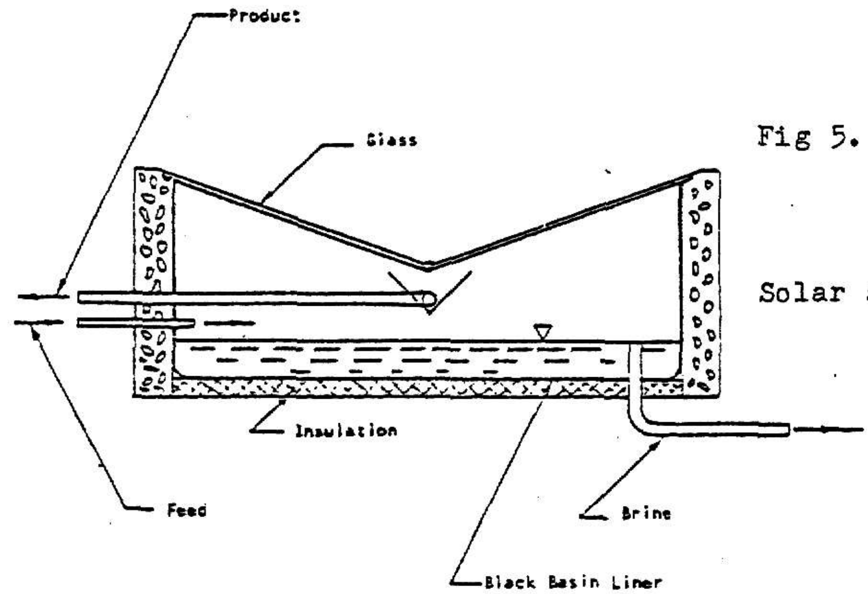
a) simple basin type solar stills

b) solar assisted distillation

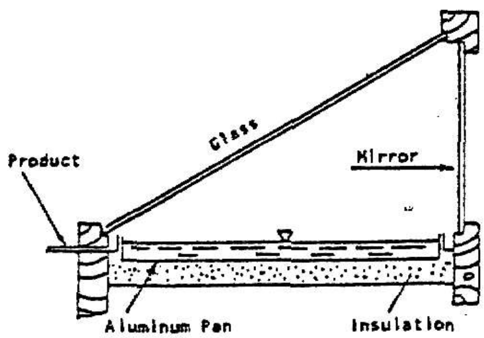
In the basin type solar stills, the sea or saline water to be distilled is kept in black bottom stills covered with air tight glass or plastic enclosure. Solar rays pass through the glass cover, are absorbed on the black bottom and heat the water. Vapor is formed and moves upwards towards the covers which are relatively cool, condensing on the underside of the glass sheet. The condensed water slides down on the sloping glass sheets and is collected in the channels provided at the lower edge of the cover (Fig 5). Production from the solar stills depends mainly on solar radiation intensity. Humidity has no effect on production. A gentle wind is favorable and production increases with ambient temperature. With a radiation intensity of 550 cal/cm^2/day, the annual average productivity of a solar still can be 3 litres/m^2/day, with the productivity increasing in summer and decreasing in winter.

Solar assisted distillation is the indirect collection and transformation of solar radiation for seperating water and dissolved salts by means of flat plate collectors. The multistage flash process (Fig. 6) preheats the sea water by heat exchange with the condensing fresh water water vapors. The warm brine is raised to a temperature of 70-90^{o}C because of the solar input energy. The pressure is decreased step wise in a series of enclosures which contain the tube bundle of the preheater. Condensate fresh water

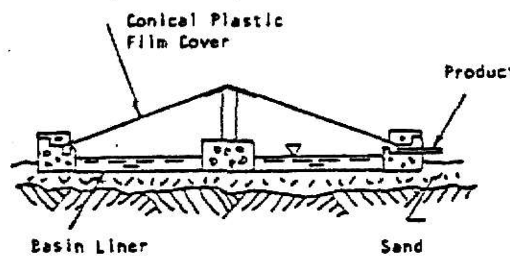
Fig 5. Solar Stills



Solar still(schematic)

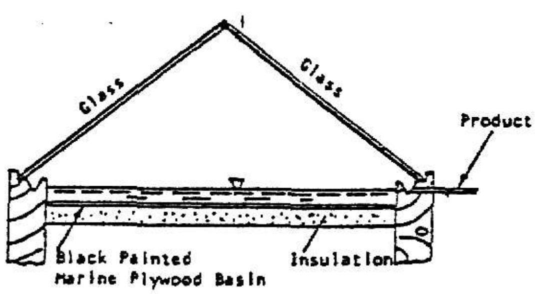


SOLAR STILL NO. 1

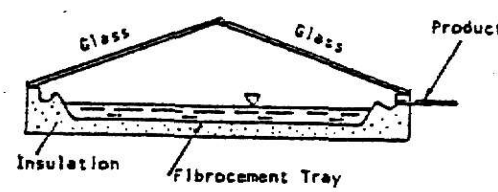


SOLAR STILL NO. 2

Various types of solar stills developed and tested at the University of California, U.S.A.



SOLAR STILL NO. 3



SOLAR STILL NO. 4

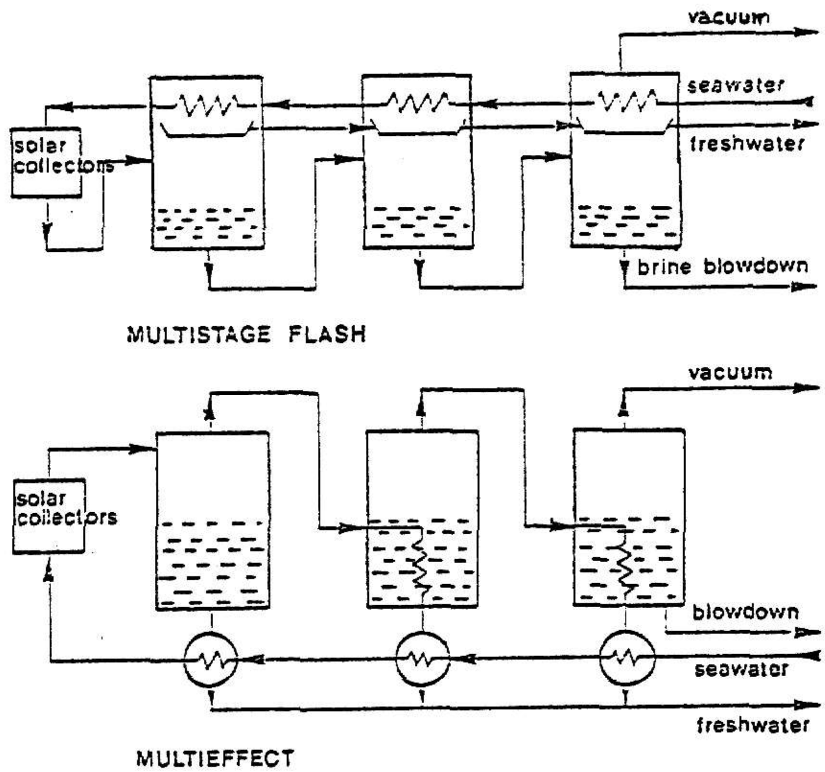


Fig. 6 is the schematic layout of solar distillation by : Multistage Flash Process and the Multieffect Process.

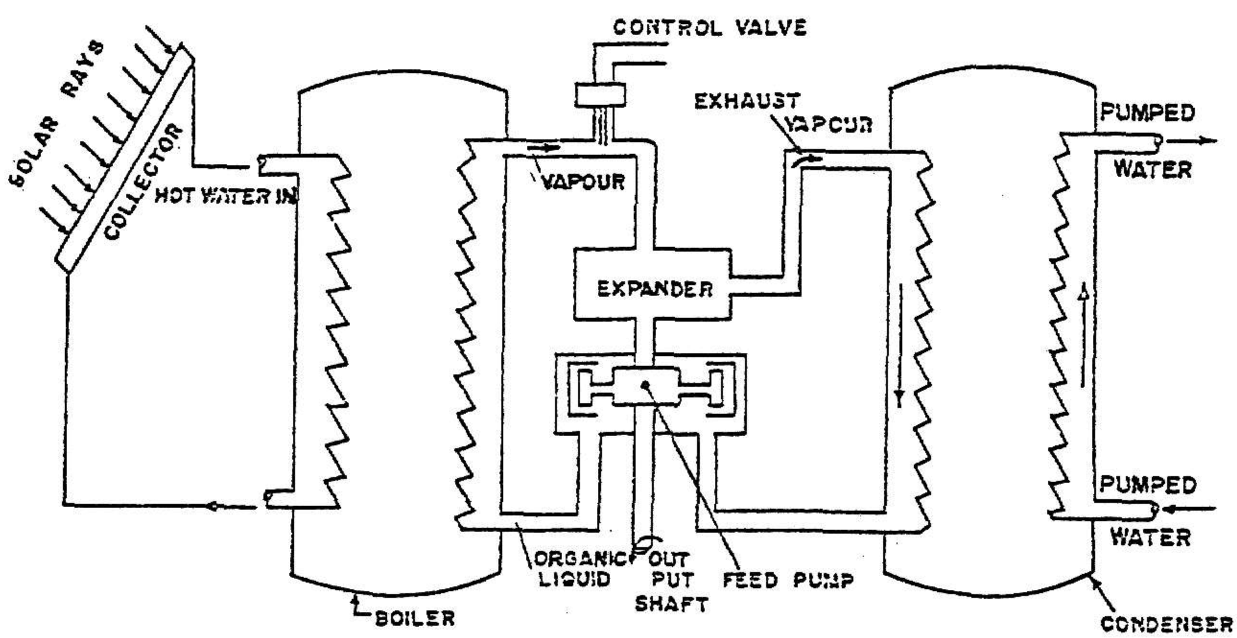


Fig 7 is the schematic diagram of the 1Kw Abhimanyu Solar Pump developed at the National Physical Laboratory at New Delhi, India.

drips from the bundle and is collected. The highest and lowest pressure stages are kept respectively at about 0.8 atmosphere and 40 or 50 mm Hg, and the number of stages is such that the overall temperature differential is about $2^{0}C$ per stage.

4.6.3 Solar Drying: Solar drying can be classified mainly on the basis of the mode of heat transfer employed, that is radiation or forced convection. Radiation dryers have a common space for collecting solar energy and for drying the product. There are holes in the bottom and top of the space to allow for ventilation of evaporated moisture. The materials for drying are placed on trays at one level, and exposed to the direct radiation from the sun, and there are no controls except the adjusting for orientation to the sun. Convective driers have separate areas for collection of solar energy and for drying the product. Heat can be transferred from one area to the other by air or water.

Solar radiation is the principal energy source for salt farms which treat sea water/inland brine in three stages to produce common salt.

1. reservoirs (3^{0} to 6^{0} Baume) where in sea water is taken in.
2. condensers where in brine is concentrated to precipitate out calcium salts, and
3. crystallizers (24^{0} to 29 Baume) where in common salt is precipitated.

The area required in the manufacturing process are 35 percent for reservoir, 45 percent for condensers and 10 percent for crystallizers. For every ton of salt produced 45 m^{3} of water must be evaporated. Evaporation depends mainly on the intensity of solar radiation, air temperature, humidity, direction and velocity.

4.6.4. Solar Pump : The transportation of solar energy into mechanical energy helps to drive irrigation pumps. Where water is available at a depth not exceeding 30m, solar water pumping technology can be used. Solar water pumping system in the range of 2-15 Kws are required in the developing countries. The strategy followed in India for the development of the rural areas are:

1. development of 2-5 HP solar pump of the modular form, so that when pumping is not required, the same system may be used to produce mechanical or electrical energy for industrial or domestic use.
2. development of 19-100 KW solar power plants.

Solar pumps can be operated with solar energy converted directly into electricity or by using thermal energy itself to heat a working substance which may operate the engine. The Indian Abhimanyu Solar pump is a 1KW water pump developed by the National Physical Laboratory in New Delhi (Fig 7). The primary components are flat plate collector array and an organic rankine cycle engine. During operation, heat transfer fluid flows through the collector array and is heated to a temperature ranging between 80-95^{0}C. This hot water is used to vaporize a low boiling point organic liquid in a reverse flow heat exchanger cum boiler. The high pressure organic vapor is then used to drive the expander of rankine cycle engine. After leaving the expander the organic vapor is condensed in a condenser where the pumped water is used as a heat sink. The condensed organic liquid is pressurized and then pumped back into the boiler with the help of a reinjection feed pump mounted and driven by the shaft of the expander. This system is so versatile , that it can also be used to generate electrical power, drive a mechanical system and pump water.

4.6.5. Other potential solar system : The other areas of solar energy application in the developing countries in the future are : solar engines to produce electrical power, thermoelectric conversion of solar energy into electricity directly, solar ponds for collecting and storing solar heat, solar concentrators, energy plantations, algae ponds, biogas production and controlled environmental green houses.

The existence of the various solar technologies , and their transfer to the LDC's, to improve the living environment and accelerate the development process, has gained considerable momentum recently. The concept of using renewable energy sources in various regions of the world can provide a viable alternative to the conventional energy sources . In general there are two basic approaches for harnessing renewable energy sources. The first one advocates the use of each resource in a manner that is best suited from the resource view point to minimize the hardware used. Typical examples are wind driven water pumps, flat plate collectors to supply hot water, direct biogas supply for cooking. The second approach is the conversion of all resources into electrical form for distribution to consumers . In this case some form of chemical energy storage like batteries and hydrogen storage would be necessary. The advantages of this approach are:

1. energy can be made available on demand.

2. integration with future expansion of conventional utility grids.

The first approach is more appropriate for rural application in the LDC's, where as the second has future possibilities. A prudent choice is to properly combine the two approaches. Energy systems for harnessing renewable resources appear expensive because of the underpricing of the existing technologies. With further research and development they can be made competitive, and would be very useful for the rural areas of the LDC's.

Chapter 5

CASE STUDIES IN THE LDC'S

5.1 Criteria for Appropriate Solar Systems

Renewable energy technologies must be appropriate in meeting the real needs of the populations and societies they serve. Not all solar based programs or technologies are necessarily appropriate and as such certain criteria for appropriate solar technology have to be established. Appropriate solar technologies should have the following:

1. A real need of a society in meeting the demands for food, clothing, shelter, water, health, and employment.
2. Recognise the need for local fabrication, maintenence and control.
3. Be under the overall control of the community where it is being used.
4. Be environmentally appropriate and compatible with the overall ecosystem.
5. Make use of appropriate material, which are able to resist decay from local climate and operating conditions.
6. Be socially and culturally adaptable to the needs of the popu population.
7. Contain low foreign exchange, so that developing countries do not have to rely on imported technology.

8. Provide independence of operation both from a technical, financial and administrative point of view.

9. Energy should be used to satisfy the basic needs of the society first and secondly should be used for other uses.

10. Reject the use of exotic materials and systems, over which there is no local control.

11. It should depend on local research and development and encourage creativity and improvization.

Appropriate solar technology should have independence of operation, financing, decision making, etc because in developing countries, bureaucracy make operations difficult and stifle creativity. An appropriate technology addresses the real needs of the society, like the need for food, clothing, shelter, water, health, employment, etc. Renewable resources based on the sun must respect these criteria contingencies if they are to remain appropriate. Solar energy itself is appropriate because the source of the energy is natural and renewable. But to make it relevant, one has to be conscious in making solar energy sensitive to the needs of the community. The following case studies selected from various developing countries have been done, taking into consideration the above mentioned criteria for appropriate solar technology. They have not been evaluated either from the social, economic or technical, aspect, but are considered relevant in the sense that they have been successful in the region where they have been applied. In trying to relate these systems to Bangladesh one has to take into consideration the prevalent characteristics in that country which is common with those of the selected case studies.

5.2 Case Study I: Small Scale Hydropower.

Papua New Guinea: Micro-Hydroelectric projects for rural development.[1]

The Baindoang micro-hydroelectric project was initiated as a result of a seminar on rural electrification at the University of Technology. Baindoang located on the southern slopes of Saruwaged mountain ranges is rugged country with major rivers flowing close by and has an annual rainfall of 200 to 300cm. The initial planning was decided by the local residents who provided their labor, and the organisation for the project. The plan provided for a small dam to be built on a stream with part of it diverted and flowing through an eighty millimeter penstock and pass through a pelton wheel turbine. With a flow of about eight liters per second, the electric generator would have an output of about seven killowatts. The cost for the project was initially estimated at U.S. $12,600, but the final cost was $14,980 of which approximately ten percent was contributed by the local residents.

The impact of the Baindoang microhydroelectric project was that it helped to meet the developmental needs of the local village. The project did not require the development of a new technology, nor the modification of known technology. Besides the involvement of the local residents from the initial planning of the project helped in the awareness of the community and the acceptance of the project.

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[1] Donald D. Evans and Laurie N. Adler, Appropriate Technology for Development: A discussion and case histories, Westview Press, Boulder, Colorado, 1979, pp397-409.

5.3 Case Study 2 : Biogas Technology

Tanzania Biogas Generator [2], (Figure 8)

The biogas technology, was imported into Tanzania from India by the Arusha Appropriate Technology Project in 1978 and since then these generators have been quite successful in the rural areas. A typical generator has a diameter of one and half meters and are made of six fifty gallon oil drums with their top and bottoms removed and then flattened out. They also require ten meters of 2 to 3 angle iron or 1½ to 2cm diameter pipe as the radii on the open end side of the tank. One meter of 4cm diameter pipe is needed as a central hub and a three meter pipe of small diameter pipe is used as a guide over which the central hub rides. Other parts include a common plumbing valve, a few pieces of hardware and some heavy tree branches. It required two men to make a methane generator in about 4 days, and the selling price in 1979 was $100 to $220.

The gas requirement for cooking three times a day are approximately 1.4 m^3 /day per family, which could be supplied by the wastes of three or four cows. On the other hand to supply the power for the lighting needs of a family at the rate of 1 Kwh/day would need to operate, a generator by biogas producing 4-5 Kwh/day and that would need the waste from two cows. Furthermore the same biogas could be used to provide mechanical power at the rate of 1 Kwh/day.

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[2] Tanzania National Scientific Research Council, Workshop on Solar Energy for the Villages of Tanzania, 1978, p.31.

Solid Drum Biogas Generator

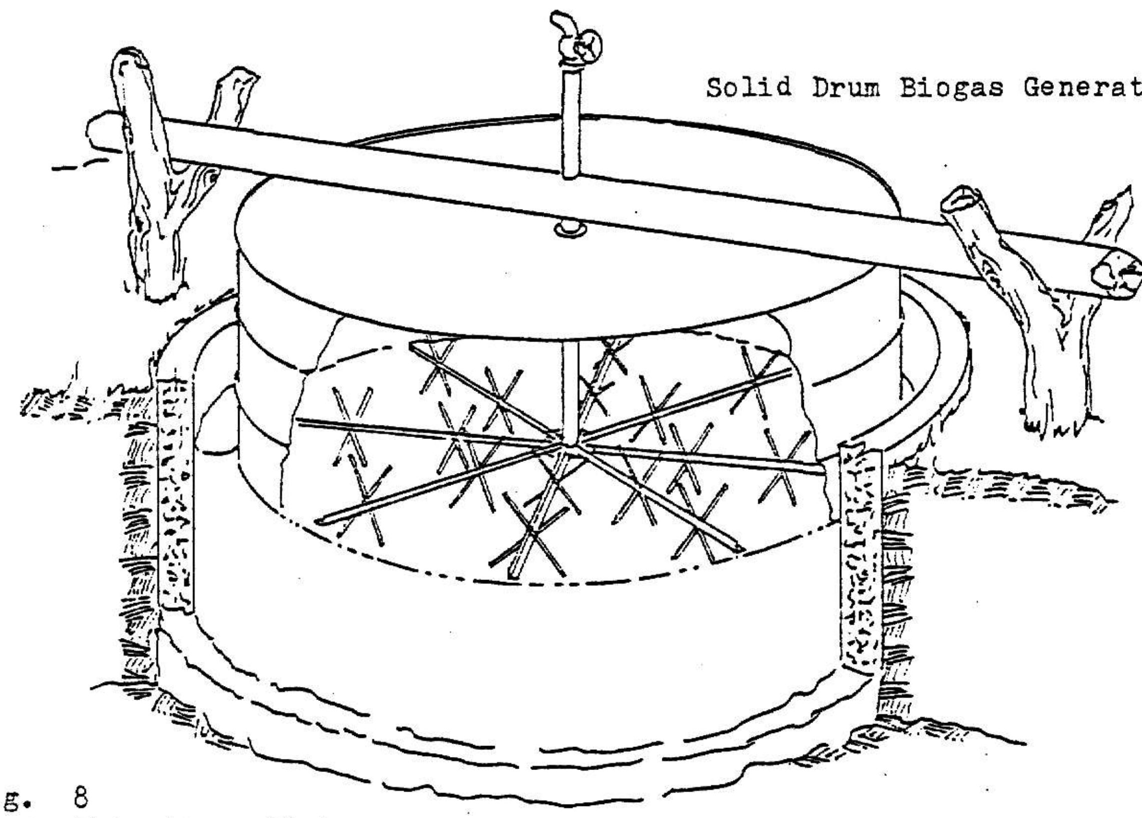
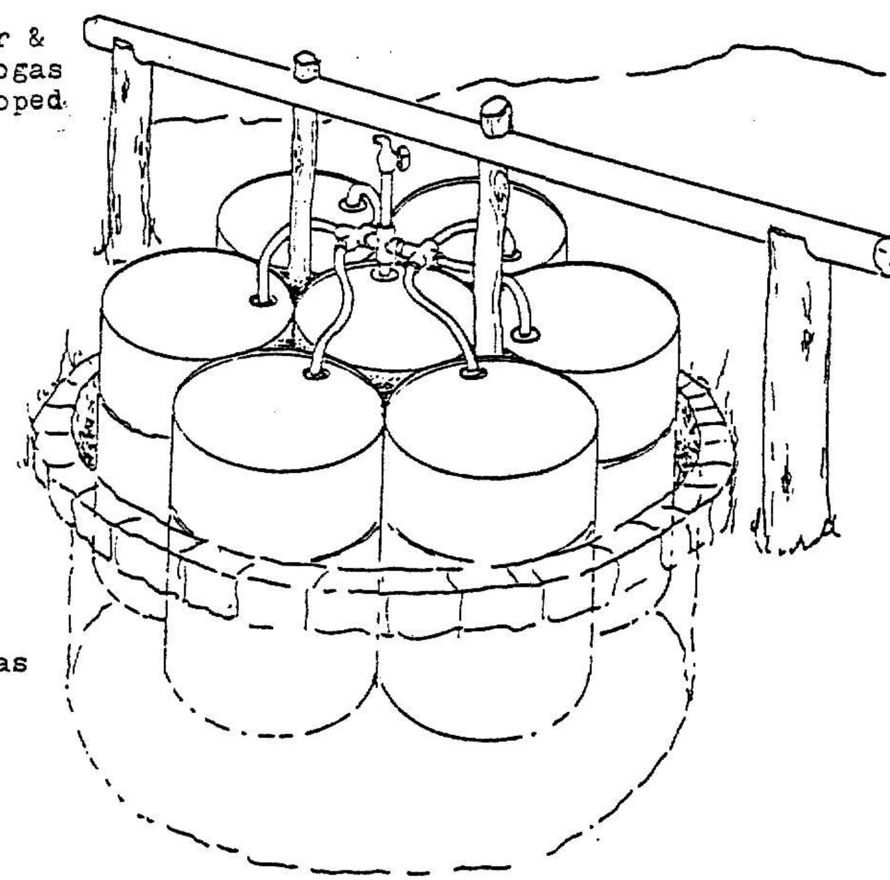


Fig. 8
shows the perspective
of a solid drum
biogas generator &
a seven drum biogas
generator developed
and in use in
Tanzania.



Seven Drum Biogas
Generator

Another potential use in Tanzania was the replacement of wood and charcoal by biogas in firing clay pottery which is a rural industry. For small scale production $8m^3$ of methane over a period of five hours were required to fire earthernware to $1000^{o}c$ in a kiln having a volume of $6ft^3$. This is equivalent to about $13m^3$ of biogas which could be supplied by a four day accumulation of the wastes of five cows. The heat energy from a single family biogas plant was calculated to cost less than one tenth the equivalent energy cost of electricity.

The following benefits have resulted from the introduction of biogas generator.

1. The users benefit in that their cooking fuel cost are reduced to zero once the cost of the methane generator has been paid for.
2. It frees the villages from the use of charcoal and firewood, and cuts down the daily labor for gathering of fuel.
3. The villages can use the slurry in the tank as nitrogen fertilizer for agricultural purposes.
4. Besides the methane can also be used for lighting, and running generators for mechanical power.

5.4 Case Study 3: Windmill Technology

Windmill for rural use.[3]

Windmill technology have never been exploited in India

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[3]Francis de Winter and Michael Cox, ed., Sun: Mankind's Future Source of Energy (Pergamon Press, New York, 1978, p.1796.)

because winds are of low speed and vary appreciably during the seasons. As such to design a windmill to the rural conditions of India it must work efficiently in winds of 10-20 Km/hr range provide at least 100 W of power in order to displace the use of a pair of bullocks which typically provide about 250 W of power. Furthermore to encourage individual ownership the windmill should cost Rs 1000 or the equivalent price of two bullocks, the technology should be labor intensive and simple to use. Any maintenance or repairs should be within the skill of the vilagers themselves.

According to that criteria, two prototypes were designed with a sail area of $8m^2$ each. The slight difference between the two were in the sail profile and the rotor support. The support structure for the windmill consisted of a pair of A-frames with cross members and guy wires. The lower parts of the A-frames are strengthened by diagonal members, which are fixed to it. The poles for the A-frames were made of cut timber, of 5cmX10cm nominal thickness. All joints were of mild steel bolts of 12mm diameter and the guy wires are of galvanised steel. The rotor based on the savonius type consisted of a vertical shaft in the form of a galvanised steel pipe with welded end fittings. The shaft is supported by a self aligning brass at the top and by a ball bearing at the bottom. The bottom end of the shaft carries a brake/power take off drum and an end crank for driving a pump. The wires between the end plates form the support system for the sails which are of jute canvas.
As the major use of the windmill is for pumping of water, a positive displacement pump was used. The pump consisted of the casing of a

pnuematic tyre blocked by two discs, one at each bead thus creating an enclosing volume. Since the pneumatic tyres are designed for operation at an internal pressure of around $2Kg/cm^2$ corresponding to about 20 meters of water, it can be used to pump water to that height.

The prototype windmill based on a novel sail-type Savonius rotor has performed quite well and has pumped 150,000 liters of water making it a viable entity. The following has been the rough breakdown of the cost:

Item	Cost in Ruppees	
	materials	labor
1. Tower including erection	350	250
2. Foundation	130	70
3. Rotor & plates including paints paintings	390	160
4. Sails with paintings	120	80
5. Shaft, bearings, sail, support wires and fittings	260	220
6. Pump	260	120
7. Transmission	190	90
8. Plumbing	150	-
9. Installation of rotor, transmission pump and plumbing	-	150
Total	1850	1140

The prototype has proved to be feasible to the rural areas of India, even though the wind space is not very strong. The use of local materials and resources in the design makes the use of windmill an appropriate technology and they compare very favorably with the present use of dry cells for producing which costs Rs. 300 per Kwh.

5.5 Case Study 4: Solar Pump Technology.

Development and performance of solar water pumps,[4] (Figure 9 & 10).

In India certain types of solar water pumps have been put in operation and studied over a period of time. These include: an air-cooled solar water pump of 2600 liters/day; a water cooled pump of 120,000 liters/day ; and a direct cooled pump of 100 liter and 10,000 liters per cycle. The 2600 liters per day air cooled pump has two collectors of 2.6 sq. meters in area, a flash tank of 145 liters and a water tank of 2600 liters pumping capacity.

In the morning the flash tank is checked for the presence of water by locating the interface through the sight glass. If water is present it is drained,otherwise water enters the collector and drastically reduces the efficiency of the collector. If water is not present in the flash tank the working fluid is allowed to flow into the collectors.When pressure in the flash tank exceeds the operating pressure which corresponds to the discharge head, valve in the vapor line connecting water tank is opened allowing vapor into the water tank affecting pumping and is closed on completion. After sunset the heat from the spent vapor is rejected by radiation and convection through the collector. The vapor is condensed in the collectors and flows back to the flash tank. As condensation of vapor proceeds , partial vacuum is achieved and water starts entering the water tank through check valve. The next morning if the condensate has not over flown into the flash tank a small quantity of water is injected from the overhead tank to displace the same.

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[4] Francis de Winter and Michael Cox, ed., Sun: Mankinds Future Sources of Energy, (New York: Pergamon Press,) p. 1917.

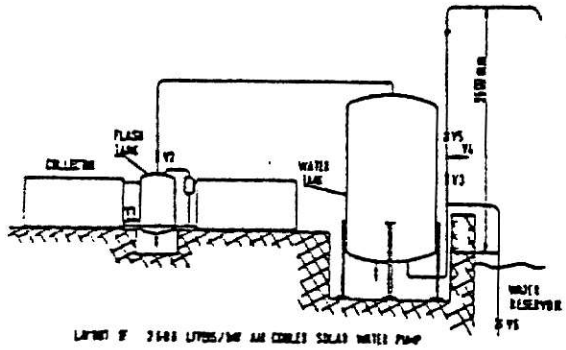

Fig. 9 is the schematic layout of an air cooled solar water pump.

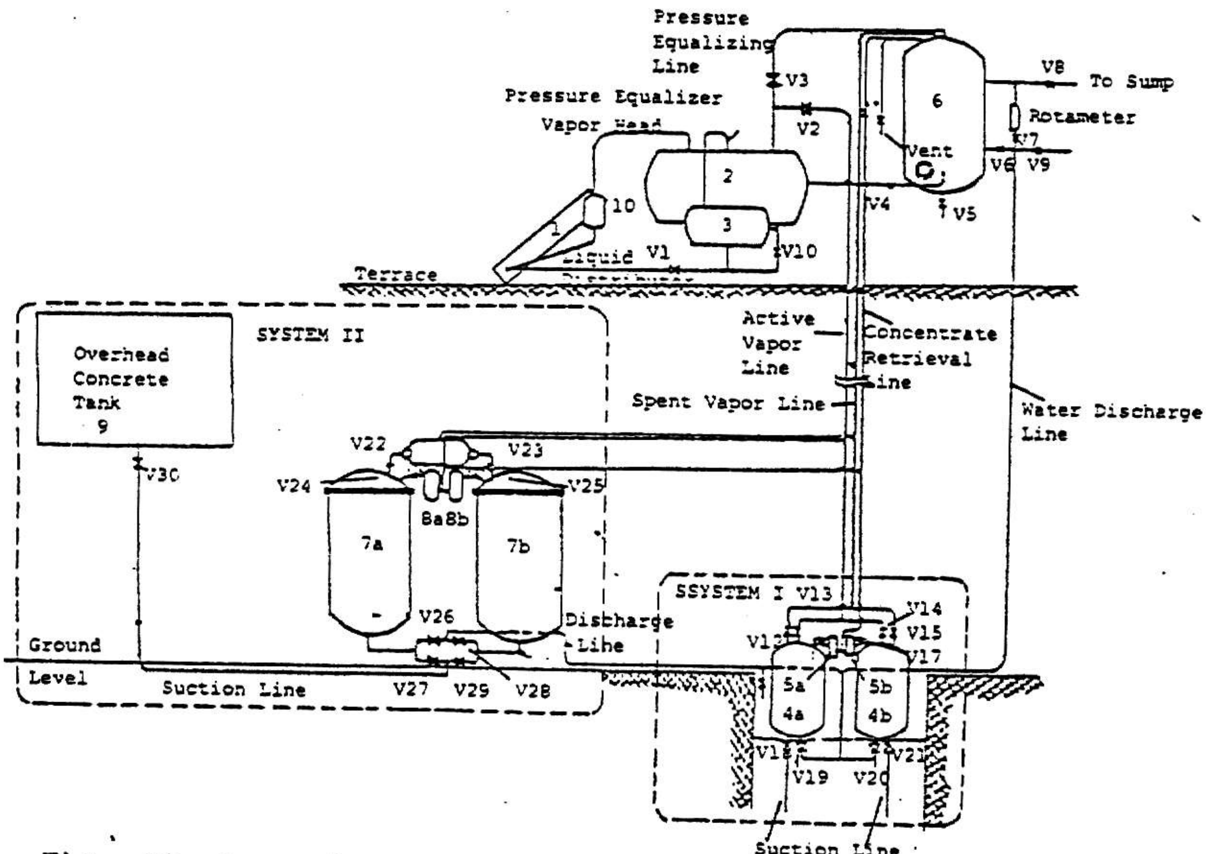

Fig. 10 A schematic sketch of 1,20,000 litres/day water cooled pump.

LEGEND

1 Collector
2 Flash Tank
3 Level Control Feed Tank
4a,4b Water Tanks (Sub System 1)
5a,5b Concensate Retrieval Pumps (Sub Systems I)
6 Condenser
7a,7b Water Tanks (Sub System II)
8a,8b Condensate Retrieval Pumps (Sub Systems II)
9 Overhead Concrete Tank
10 Separator
⋈ Valve

6. Reservoirs and irrigation canals can be used for growing water plants as bio mass and water evaporation would be reduced.

The various aspects of a biomass energy systems are:

A. Selection of plant species:

The plant selected for bio mass production for a particular area would depend on the climatic conditions, water availability, yield rate of the plant and ease of harvest. Plants which are considered to be the best bio mass producers are : water hyacinth and other aquatic plants; algae; certain types of grass like Napier and Sudan grass. Water hyacinth is the most promising and has a yield rate of 148 tons (dry)/hectare /year ; Pangola grass has 55.3 tons/ hectare/ year; Sudan grass has 186 tons/ hectare / year.

B. Water availability :

The availability of water from rivers, reservoirs, lakes, canals, ponds and tanks are very important for bio mass cultivation. The region should also have heavy rainfall of at least 100 cms annually.

C. Power plants :

The biogas produced from the bio mass energy system can be used in power plants with the following type of engine: reciprocating engines, gas turbines and organic Rankine cycles.

D. Cost factors :

The main items of cost in a bio mass energy system are :

(a) Initial costs which include land cost, reactors, gas storage tank, engines, generators, transmission lines and civil works.

(b) Running cost which include inputs, harvesting, processing, labor, The water cooled pump is designed for a discharge head of 12 meters and a capacity of 120,000 liters per day. It has a total collector area of 34.56 m^2. The collectors, flash tank, level control feed tank and condenser were situated on the terrace of the building while the water tanks and condensate retrieval pumps are placed at the ground level. This simulates a 12 meter deep well pump operation.

5.6 Case Study 5 : Bio Mass Technology

Bio mass energy for rural areas. [5]

The basic feature of the bio mass energy system relies on plant with prolific growth rate. The harvested plants are finely chopped, slurried with water and fed to bio gas reactors. The gas which is generated are 65 % by volume methane and 35 % by volume carbon dioxide which is cleaned and stored under pressure. It can then be used for running gas engines, turbines for producing electric power and the slurry can be used as fertilizer.

For developing countries bio mass energy system has the following advantages:

1. In comparison to thermal power the cost for fuel transportation is eliminated and investment on transmission lines are cut down.

2. Dispersed villages can become self sufficient in energy.

3. The system is ecologically sound.

4. The technology is simpler than other solar energy devices and the initial cost is far lower.

5. The economy of the villages is improved because of the large quantities of organic fertilizer produced as a by-product, which would be very useful to rural agriculture.

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[5] Ibid, p. 824

maintenance, depreciation, interest on capital, etc. The following is the cost analysis for the electrification of a village in India with a population of 1000 and having an agro based industry.

Required energy consumption (rural areas)..........0.2 Kwh/head/day
or 2000 kwh/day for the village.

Plant yield....... 148 tons (dry)/hectare/year or 406 kg/hectare/day

Bio gas yield..... 375 lt./kg. dry plant

Gas yield......... 0.375 x 406 = 152 m^3/ hectare

L.C.V. of Bio gas = 4900 k.cals/m^3

Thermal efficiency of engines with efficient heat recovery= 50%

Mechanical output= 372 x 10^3 k.cal/hectare/day.

Electrical output (generator efficiency 90%) =390 kwh/day

Area required= $\frac{2000}{390}$ = 5.13 hectares

Approximate size of power plant required = 200 kw

Estimated output of digested slurry= 148 x 5.13 x 0.5=580 tons/year

With a 50% allowance, about 8 hectares of water hyacinth plantation will supply the energy requirement of the village.

5.7 Case Study Analysis

The case studies discussed earlier have to be evaluated from the context of their application to Bangladesh. The solar systems at present in use and being tested have proved quite successful in those countries. As such the diffusion of that knowledge to other developing countries would not be a critical problem. The important fact is that the technologies and devices discussed have already proven in practice over the centuries in various cultures and in diversified societies. Furthermore they are in use in certain countries of the LDC's, for instance in China there are an estimated 7 million bio-digestors and 70,000 mini hydroelectric generators. Indeed the bulk of the elctricity for some three-quarters of the rural communes of China are furnished by these generators with an average capacity of 40 killowatts. The technologies have also been proven in India where nearly 100,000 biogas digestors are in operation; in Holland and the plains of North America where windmills have been vitally linked to development; and in New England where water wheels were a major source of mechanical power until cheap oil displaced them.

The strategy at present being followed in Bangladesh is reliance on fossil fuels, though most of it have to be imported from abroad. There are certain plants built by the council of scientific and institutional research which are being used as pilot projects. Long range plans being studied at the Engineering University include the combined use of water hyacinth and cow dung for village size digester plants. But at present there is no commercial plant in operation as yet.

The case studies stated earlier, have certain draw backs. Pilot plants and prototype devices have proved both economically and technically feasible in many countries. But there is a general lack of investigation and detailed analysis as to why appropriate solar technology have not managed to make a break-through. There is also a lack of objective assessment of the whole host of appropriate technologies that are linked to a particular solar system. A solar system can be appropriate only when it is so at all stages of its application to a community. Like for instance in the case of biogas system there are considerable number of potential benefits but the problem remains of evaluating the conditions under which these benefits can be reaped."Macro evaluations often assume that most of the available inputs will go directly into the digester, but micro evaluations suggest that alternative uses of inputs and seasonal fluctuations limit their availability in practice." [6] Local factors like climate, cropping pattern, terrain and social practices will influence not only technical design but also costs and benefits. Another disadvantage found from the case studies is the lack of and close cooperation in research and development in the LDC's, regarding solar **technology.** This ultimately results in **duplication** of efforts and wastage of resources..

The strength of the case studies show that even with low priority the pilot projects have proven successful, by themselves. For climatic reasons the countries of the LDC's, will constitute the chief areas for solar energy application and as such some of the major progress will come from these regions. "According to the experience of the German solar energy program certain measures ought to be instituted." [7]

They are as follows:

A. For the application of solar technology compilation of data

[6] A. Barnett, L. Pyle & S.K. Subramanian, Biogas Technology in the Third World: A multidisciplinary Review (Ottowa: International Development Research, Center, 1978.)

[7] H. Klien, P.J. Heinzelmann, F.J. Friedrich and H.F. Wagner, "Federal Republic of Germany Program; Technology for utilization of Solar Energy," ed. F. de Winter M. Cox, Sun-Mankind's Future Source of Energy,(New York: Per gamon Press, 1978.) p. 45

on a global basis is important. It should record the hours of sunshine, global radiation, temperature, precipitation, humidity, wind velocity, etc.

B. The successful introduction of a solar system requires knowledge of regional needs and the chronological course of requirements.

C. The components and systems should be standardized, so that the reults and data can be reproducible and solar technology commercialised.

D. In order to improve the level of knowledge concerning the ecological impact because of the the wider use of solar technology a basis has to be created for decision taking and policy making at the administrative, economic and industrial sections.

5.8 Conclusion and Recommendations

Economic development throughout history has consisted of finding substitutes for human energy. Yet the majority of people living in rural areas in the developing world still must rely largely on human muscle for their daily livlihood from the soil or the sea; to till the land, harvest and process their crops, grind grain and haul water and wood. They have no lights at night and lack means to preserve food and dry their crops. Until they have more modern energy sources the villagers can make only limited economic progress. The awareness that fossil fuel is limited has had a profound impact on the economic growth of the developing world. Consequently, if economic progress is to be made a newer form of energy source has to be found and used. The use of renewable resources derived from solar power is the strategy for the future. It is recognized that solar technology is a multi-disciplinary area of activity with potential for successful economic application in both industrialized and developing countries.

In this report the prospects for solar energy utilization in Bangladesh have been outlined. These systems are seen to be appropriate for rural energy developments within a national energy program. If solar energy is to make a significant break through in Bangladesh, many factors have to be realistically assessed. The technical aspect of solar system are important, but for Bangladesh and other developing countries the socio-economic considerations, education, training, planning and implementation within development programs are more vital.

Since Bangladesh solar scientists have very little data on the research and development of the technology at their disposal, they have to rely on their own efforts to collect and document the variables which would be pertinent to that country. International help along with national government encouragement would be essential in the utilization of solar energy. For this reason the initial stages of solar energy research there should start to:

a) survey the energy availability and requirements for domestic and community purposes; for pumping water, lighting, running small industries in the rural areas.

b) collect the data of solar radiation, wind speed, rainfall, etc. from the available records and to extend the network of solar radiation.

c. train personnel by organizing courses on the application of solar energy and renewable resources.

d. initiate demonstration programs with pilot projects to publicize the use of solar energy.

In order to facilitate and realize the steps for accelerating the use of non conventional energy resources, cooperation between international organizations, university research bodies and the scientific community in the country is very important. As such it is the responsibility of governments, both in the developing and the industrialized world to be aware of it and make solar technology an integral part of their economic planning.

Chapter 6

SOLAR ENERGY APPLICATIONS IN RURAL BANGLADESH

6.1 Bangladesh- Location and Physical Features

Bangladesh located in South Asia, is one of the newest developing nations, which became independent in 1971. Figure 11 shows the location of Bangladesh in relation to the subcontinent of South Asia which is surrounded by India on the west, Bhutan, Nepal and India on the north, Burma and India on the east, and the Bay of Bengal and Indian Ocean on the south. Bangladesh has an approximate area of 56,000 square miles of low lying deltaic plain, with very little change in the topography. It has a population of nearly 80 million and a density of 1460 persons per square mile. Compared to that, India has about 520 persons per square mile and the United States about 70 persons per square mile. "There are very few large towns and most people live in 65,000 small scattered villages of a few hundred to 1000 people."[1] The agricultural sector of the economy provides 60 percent of the GNP and 80 percent of the jobs. As Nurul Islam states:

Bangladesh is an overwhelmingly agricultural economy;

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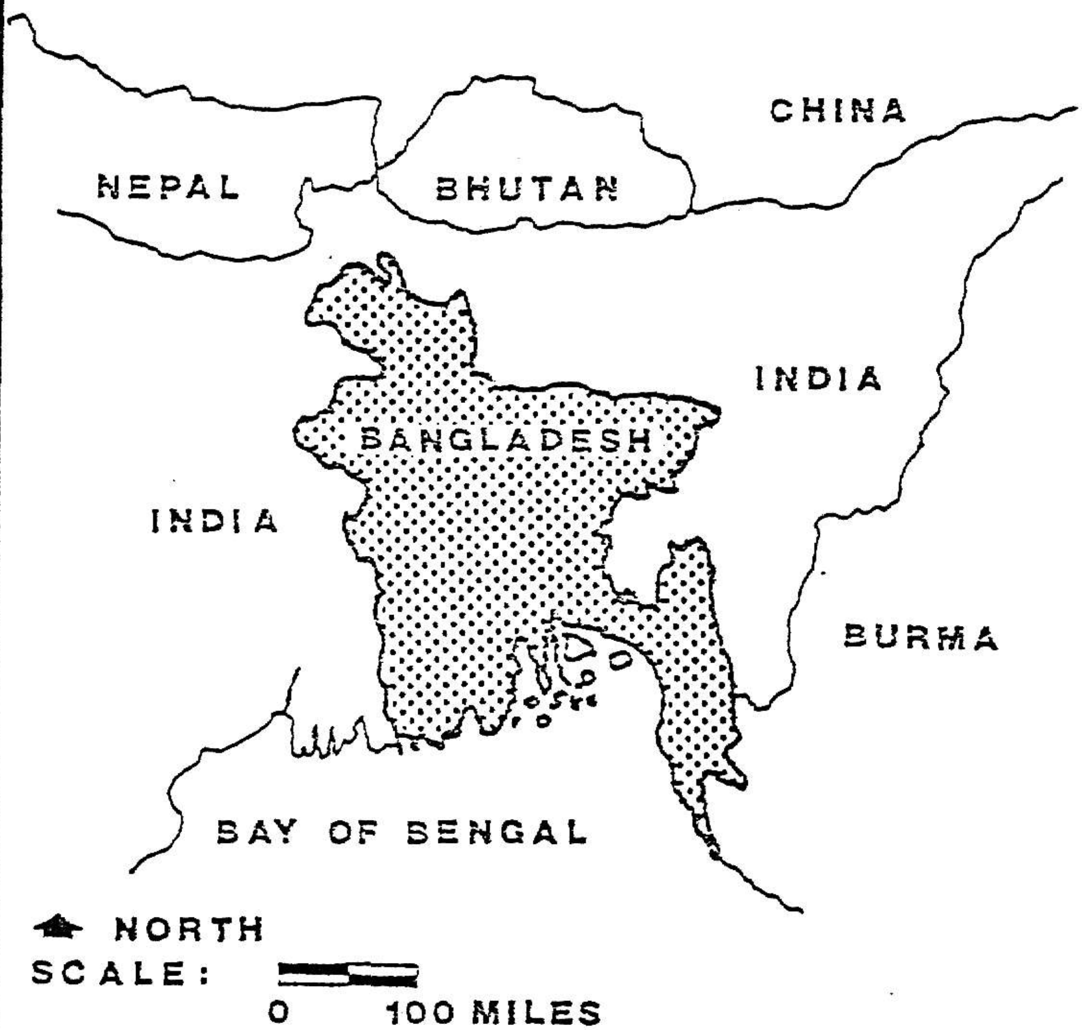
[1] J. Faaland & J.R. Parkinson, Bangladesh: the Test Case for Development, (London: C. Hurst & Company, 1976.) p. 3.



GEOGRAPHICAL LOCATION OF BANGLADESH

Fig. 11

> amongst countries with such extreme density of population, Bangladesh is unique in being so overwhelmingly rural. In absolute size it has the fourth largest agricultural population in the world, next to China, India and the Soviet Union. 2

Nearly 22.5 million acres or 60 percent of the land is under agricultural production but irrigation is carried out on less than million acres or 5 percent and since productivity is low and primitive the per capita income is only $90 percent per year. About 90 percent of the farm population own less than 7 acres or 62 percent of agricultural land. The land-less and under employed rural population is between 30-40 percent.

In Bangladesh the present population growth of 3.3 percent annually has produced tremendous pressures on the land. Land is scarce and is the most important resource for Bangladesh. Because of the limitation of fossil energy and mineral resources, land becomes all the more important, and is critical to its economic development.

Physiography: The deltaic region of Bangladesh is a fertile alluvial plain formed by rich silt deposited by the many rivers flowing through the area. The river system of the region, which is dominated by five major rivers, and hundreds of tributeries and distributeries, is the most important physiographic feature on the landscape (Fig 12). The large and small rivers and canals, form an extensive network, which contribute to the flooding of the area during the rainy monsoon season.

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[2] N. Islam, Development Strategy of Bangladesh, (New York: Pergamon Press, 1978.) p. 2

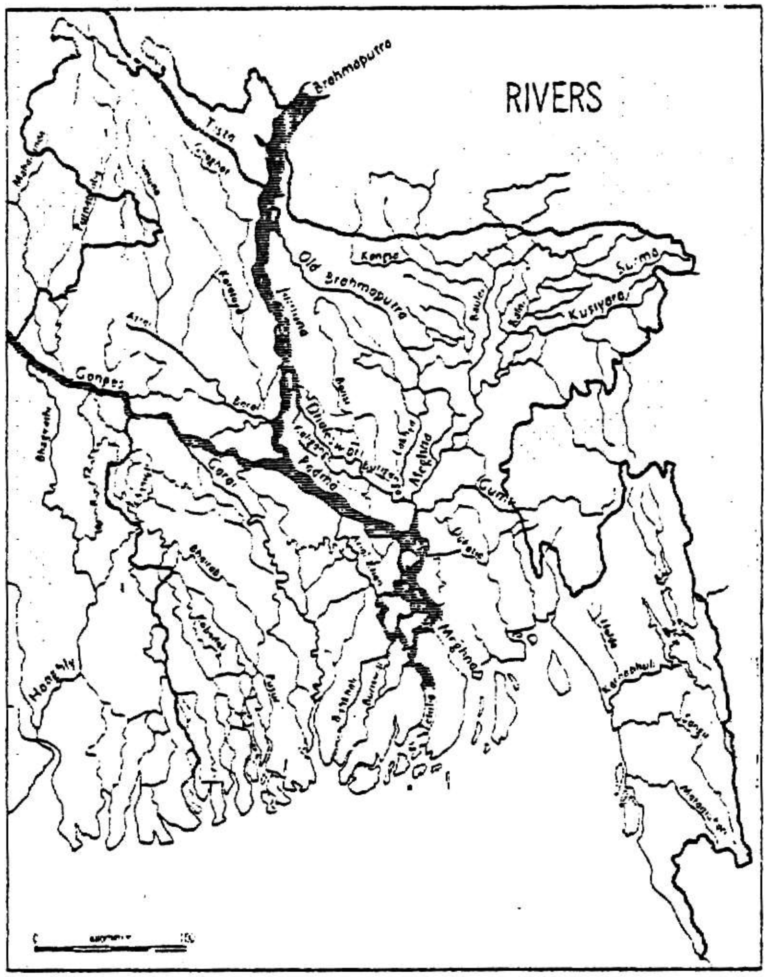


Fig. 12 shows the physiography of Bangladesh with emphasis on the rivers and their tributaries.

Climate: The climatic features of the region are heavy rainfall, hot summers and high humidity. The relatively small annual temperature variation ranges from a mean minimum temperature of 55°F to a mean maximum temperature of 80°F (Fig 13). The cool dry season has relative humidity averages of 70 percent, while during the rainy season the high relative humidity is in the mid 80's. Bangladesh is characterised by light winds during most part of the year (Fig. 14). Tropical cyclones which originate in the Bay of Bengal and the Indian Ocean, occur in Bangladesh during April-May and October-November. They normally subject the coastal regions to winds of high velocities between 100 to 120 m per hour. The mean annual rainfall ranges from 80" to 100" as shown in Fig 15 .

6.2 Bangladesh- Economy and Infrastructure

Economy: The rural economy is overwhelmingly dependent on agriculture. Under existing land tenure system, the farmers, if they own the land, owe 40 percent of their crop to money lenders or, they must share their crops on a fifty-fifty basis with the land owners.

Technology level: Life in Bangladesh is very different from that of the industrialized countries.

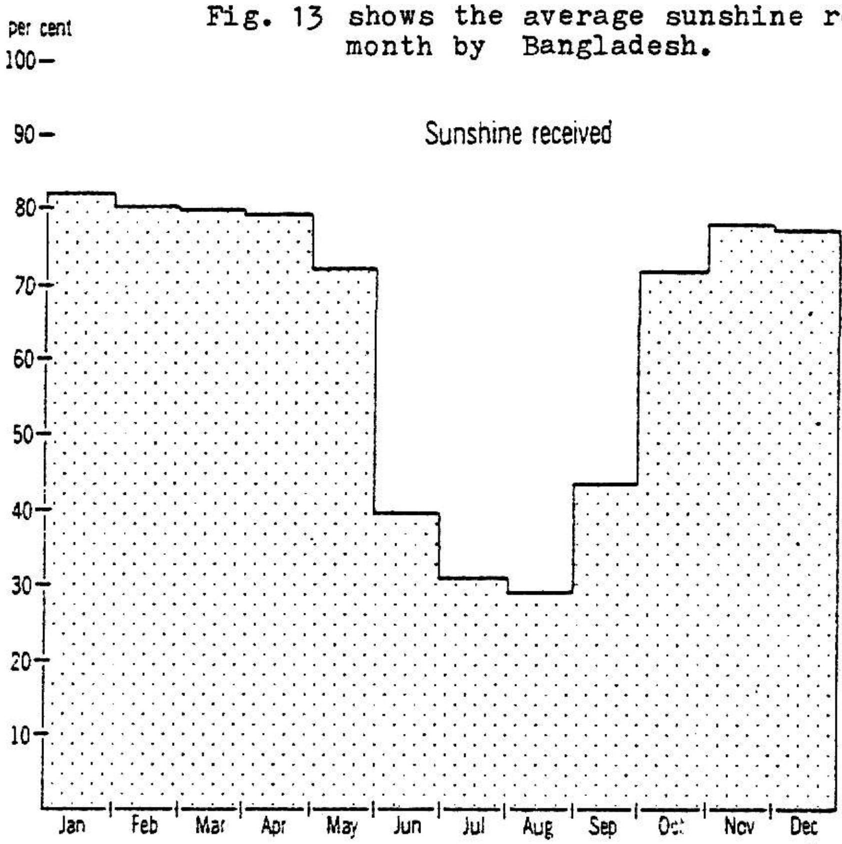
> The entire agricultural technology is medieval. A farmer generally owns a two or three acre farm which he ploughs with the help of a buffalo, a cow or bullock, using a 15 or 20 pound light plough furrowing only a few centimeters into the ground. For breaking harder clay he uses a wooden harrow or a ladder like mallet which is dragged along the field. [3]

[3] N. Ahmed, A New Economic Geography of Bangladesh, (New Delhi: Vikas Publishing House PVT. Ltd. 1976) p. 191.

Average monthly maximum and minimum temperature (°C)

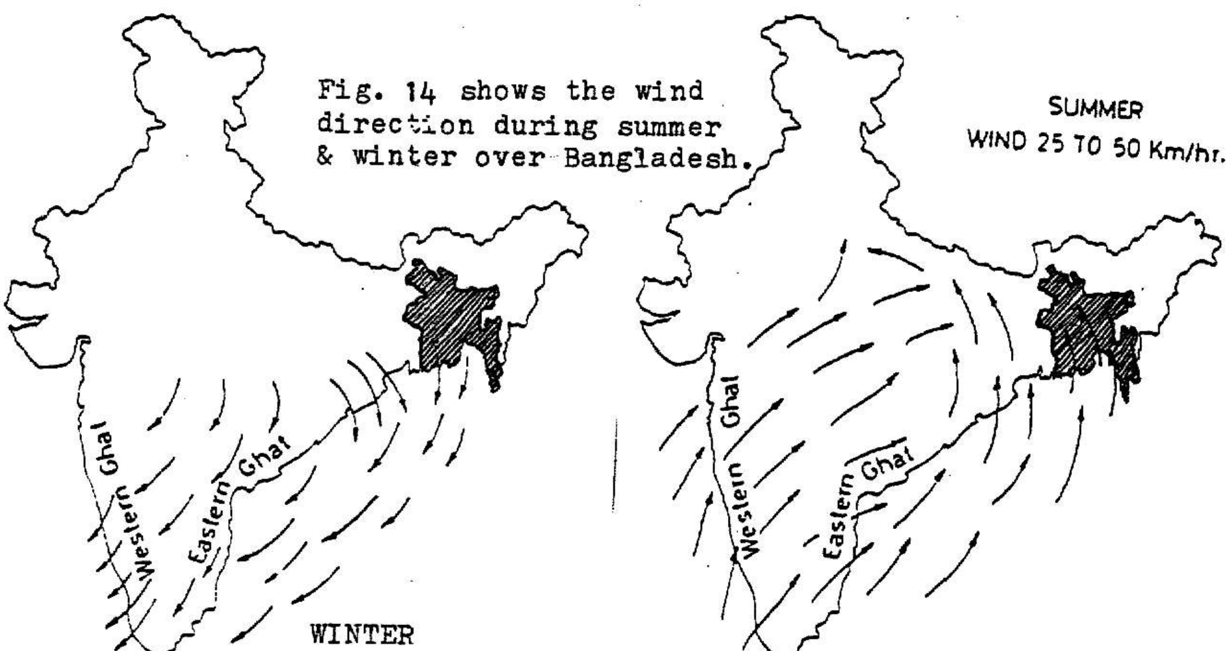
		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dinajpur	Max.	24	26	32	34	33	32	32	32	32	31	28	24
	Min.	9	12	16	21	23	25	26	26	26	22	16	11
Chittagong	Max.	26	28	31	32	32	31	30	30	31	31	29	26
	Min.	13	15	19	23	24	25	25	24	24	23	19	14

Fig. 13 shows the average sunshine received each month by Bangladesh.



Percentage of possible sunshine received each month

Fig. 14 shows the wind direction during summer & winter over Bangladesh.



SUMMER
WIND 25 TO 50 Km/hr.

WINTER
WIND 25 TO 50 Km/hr

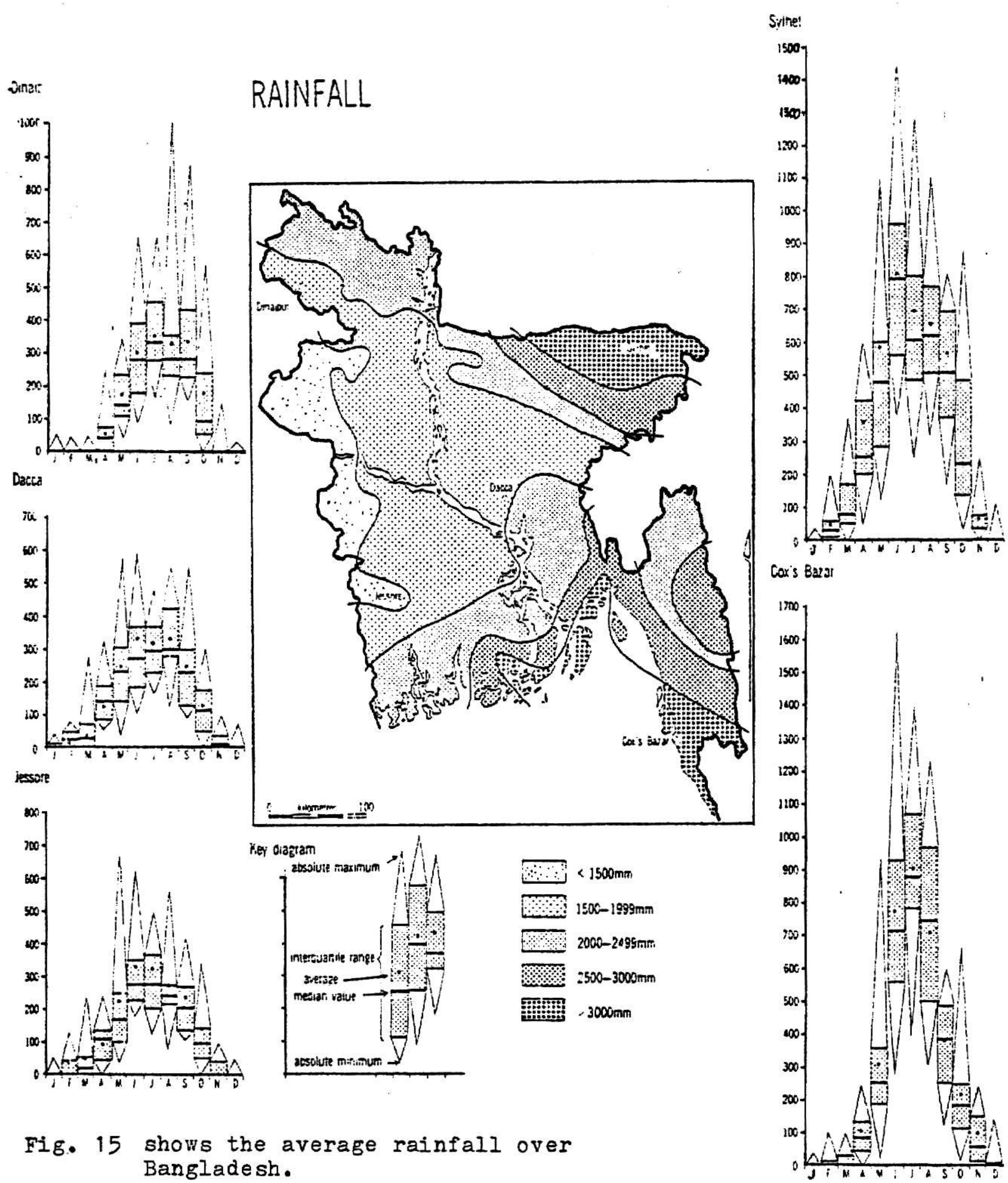


Fig. 15 shows the average rainfall over Bangladesh.

Rainfall: monthly dispersion diagrams and mean annual isohyets. All values in millimetres.

The other indication of living standard in Bangladesh tell the same story. "The country has 300 petrol pumps, 5000 buses, 70,000 motor vehicles, 2000 miles of railway, 50,000 telephones, 300,000 radio sets, and 10,000 television sets." 4

Transportation: The physiography of Bangladesh, in general, limits the expansion of roads and railroads, and the major form of communication linkage is by means of rivers. Approximately 75 percent of the villages in the rural areas are at least 5 miles away from a modern means of transportation, and people have to walk the distance between the villages and the station points. Construction and maintenance of roads and railroads are expensive because of the physical terrain, natural features, and lack of hard rocks and stones.

Dwelling pattern: The typical rural dwelling is predominantly made of mud-plastered, woven bamboo walls, mud walls or brushed bamboo walls with palm thatched roofs. The more stable houses have walls and roofs of corrugated lime cement or galvanised iron sheets. In general the villages consist of 50 to 100 dwelling units with a population of 1200-1500 persons clustered around a settlement.

Utilities: Nearly 90-95 percent of the rural areas do not have electricity, and for domestic fuel, people, burn hay stock, fire wood, and agricultural waste. The drinking water supply is from tube wells and open wells, while rivers, canals and pond

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4 J. Faaland & J.R. Parkinson, Bangladesh: The Test Case for Development, (London: C. Hurst & Company, 1976.) p. 2

water are largely used for washing and bathing. Toilet systems consist of pit privies, latrines, etc, which are temporary constructions and essentially inexpensive and lack sanitation.

6.3 Bangladesh: Energy Resources

Bangladesh is one of the poorest and least developed countries of the world. The war of liberation, and its aftermath, aggravated the problems of under development in a nation with a large and rapidly increasing population, low per capita income, narrow fossil resource base and an undiversified economy. Since the end of the 1970's, the economy of the country has been in bad shape. The major problem has been the continuing increase in the population, and the slow growth of food production. The tremendous rise in the price of imported oil, food grains, and other essential capital goods have practically reduced Bangladesh to international bankruptcy.

In order to ensure a reasonable standard of life consistent with human dignity Bangladesh needs to generate a growth of the GNP which would be at least 3-5 percent more per year than its growth of population. Since agriculture is the backbone of the economy, any growth that will come about has got to come inevitably from that sector. An extensive investment, both in terms of capital resources and manpower to the rural sector, is desirable. But with the cost being so prohibitive, the strategy of development followed so far has been of a dual economy, with very little emphasis on the rural sectors. The physical features of the land along with the disperesed settlement pattern, spread over 65,000 villages, are not only wasteful from the point of energy consumption, but also aggravate the problems. The application of new technology which is capital intensive and energy based to the rural economy is highly prohibitive because of the dispersed population. As such, the strategy which ought to be followed has to be decentralized, simple, labor intensive and based on renewable resources.

Since the mineral resource base in the case of Bangladesh is more of a speculation, agriculture, both on the short term and long term, would be the primary focus. It is obvious that in an economy in which the major component is made up of agricultural activities related to the handling of agricultural products and agricultural inputs, the rate of the growth of the economy must reflect the growth of agriculture. The energy utilized by the villagers in Bangladesh have the following features. First, people depend largely on human and animal energy to perform all basic activities and obtain their needs for survival. Secondly, domestic fuel for cooking is mainly derived from firewood, agricultural waste, and thirdly there are a few fossil fuel-based technologies of conventional design. Energy requirement at the village level fall into a number of broad and overlapping categories: subsistence, production, processing, agricultural, social and community. The energy required for bare survival in the daily needs of food and water have been threatened, because of the shortage of firewood, deforestation, and the lack of animal and agricultural waste.

Lack of nutrition and adequate diet has created a problem with the efficient use of human energy. The production of food and other essentials depends on a great deal of human and animal labor for preparing the land, weeding, fertilizing and harvesting. Processing requires the largest amount of energy for drying, threshing, grinding, preserving, converting and storing of food grains and raw materials. In addition to production and processing needs, agriculture requires energy for transportation, distribution and marketing. In Bangladesh most of the animal energy is provided by cattle, buffaloes, donkeys, horses, and elephants. Communal uses of energy increase as villages develop, and modern amenities like public lighting, schools, hospitals, community centers, and so on become common. Energy for lighting and heating become necessary for schools, shops, clinics, and small scale industries. For domestic use in the rural areas, energy is required for cooking, heating, lighting, and water. Nearly ninety five percent of cooking is done with wood, charcoal, agricultural waste and kerosene.

6.4 Methodology

Though there has been considerable awareness in the developing countries of the need to develop appropriate alternative sources of energy there is an absence of intergrated policies and programs. It seems that in most developing countries research and development is carried out on an ad-hoc basis.

> The major problems in harnessing the use of non-conventional sources of energy in most developing countries fall in three groups. One is the lack of appropriate information on the

> state of the art; the second relates to the appropriateness of the methods used to apply those sources of energy in the conditions that prevail in the developing countries; and the third concerns the reliability of such technology as developing countries would have to import. [5]

For the recommendation and application of newer energy resources it is essential to have adequate and reliable data on all forms of renewable energy sources like solar radiation, wind speed, hydraulic resources and biomass qualities. The variation and reliability of each source must be examined at the outset. For instance the ratio of direct to diffuse solar radiation is critical in determining the type of solar energy collecting system that might be proposed for water pumping purposes. The wind speed variation has to be determined because the power available from a windmill is not directly proportional to increased wind speed but increases in some cases as the cube of the wind speed. With respect to bio-mass, it is essential to monitor the supply over a period of time.

A methodology which can be used by planners at the national and regional level for the utilization of solar energy are as follows:

A: Defining existing energy resources in the country

The first criteria is the analysis of the energy resources existing in the country, with special emphasis on the availability in the rural areas.

B: Energy need analysis

There should be a breakdown of the energy requirement in

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[5] J. Rao, "Solar Energy: UNIDO Program of Action for Developing Countries" Sun: Mankind's Future Source of Energy . ed F.D. Winter & M. Cox. (New York: Pergamon, 1978) p. 18.

a rural community taking into consideration all the works to be performed. It should take into consideration all agricultural, domestic, small scale industrial and community requirement. The energy needs expressed in terms of kwh/person should be based on a year round demand.

C: Hierarchy of energy requirement

The energy required at the national, regional and local level ought to be evaluated and analysed. Those requirements which can be satisfied by solar energy should be identified.

D: Selection of attributes

For meeting the energy demand in the rural areas some of the following factors should be considered. They are capital cost of energy conversion, alternatives available, annual cost, priority on the use of a particular resource, energy availability-timewise, social acceptance, local benefits, use of localised resources.

E: Estimation of energy output

The overall annual energy output from a particular system should be estimated so as to select the most effective solar conversion system for a particular region.

F: Evaluation of the energy resources

For assessing the worth of any resource an evaluation has to be carried out on a short and long term basis. It has to be measured in terms of its social and economic impact on a community. A hierarchy has to be determined and application should be according to priority.

G: Design and adaptation

The hardware for the solar system has to be designed from its adaptability qualities at the local level. The design should also investigate the possibilities of its linkage to national or regional network.

H: Developing prototype

A pilot project should be established at a predesignated region, where it can be tested and evaluated under local conditions. Prior to its adaptation the prototype should be monitored and local modification and improvization carried out.

I: Economic and social feasibility

Since the goal of developing countries is the manufacture of solar equipment, a commercial market study has to be undertaken. This will require an economic and social feasibility study of all prospective solar hardware and their impact on society. Local research and development should also cooperate with other developing countries to facilitate the transfer of technology.

J: Promotion of international cooperation

There are many prerequisites for promotion of the international cooperation in the field of solar energy research and development. They are:

i) establishment of a national energy policy.

ii) elaboration and emphasis of the role and contribution by non-conventional sources of energy.

iii) realistic analysis of the contribution and role of solar energy.

K: Development of a national Institution

As a final step a national institution should be designated for carrying out research and development technology transfer, extension and manufacturing promotion activities. The program should not only include the technical evaluation of imported technology but also of domestic technology. It should concentrate on an adaptation, prototype fabrication, testing, techno-economic analysis, and eventual manufacture of appropriate products. The program should also include technical manpower development, technology transfer, engineering design, laboratory and field testing and cooperation among developing countries.

Inherent in the development of the above methodology is a systematic consideration of other factors which come into play such as: population distribution, growth trend and movement trends, agricultural and industrial infrastructure, development of incentives and educational support programs.

6.5 Application of renewable resources technology

Some of the technologies which are potentially applicable to the work done in the villages are: small scale hydropower, windmill, compost, fertilizer and biogas from human and farm wastes. Solar energy for pumps, driers, refrigerating, greenhouses and distillation. Other uses could be from biomass, photovoltaic, and solar ponds. Solar heated air can be used as driers for agricultural products like paddy, sugarcane, cassava, pineapple and bananas. It can also be used for alcohol production, chicken breeding, ice making, and water and space heating. Brick manufacturing from the readily available clay, which is essential for the building and construction industry in the rural areas, can be carried out by the solar technology.

Bangladesh is crisscrossed by countless rivers with their tributaries, and distributaries, and nearly 5000 miles of water ways are used for inland transportation and communication. Nearly 90 percent of the villages are within 2-5 miles from the river or its tributary. Consequently, rivers have played a tremendous role in the socio-economic life of the rural areas.

6.6 Small scale hydropower

Small scale hydropower technology can very easily be applied to the rural areas on a decentralized basis. In Papua, New Guinea, a seven Killowatt plant was installed at Baindoang over a period of 2½ years on a self help basis. The entire project with its power station, generator, and dam, cost about $14,980. In Indonesia, water from a small irrigation ditch about five meters wide has been succesful in driving a generator and producing 2-6 Kilowatts of electricity. "An irrigation canal in Lin Hsien in China has a series of small scale hydroelectric plants built alongside it, taking advantage of the progressive drop in elevation. The first plant is capable of generating 250KW, and is located at the bottom of a 15 meter drop, thereafter for every five meter drop there is a 40 Kw turbine." [6]

The current technology regarding the manufacture of small scale turbines is very reliable and quite inexpensive. The

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[6] National Academy of Sciences, Energy for Rural Development: Renewable Resources and Alternative Techniques for Developing Countries, (Washington D.C.: 1976) p. 153.

Leffel packaged units range in size from 0.5Kw-10Kw and cost from $3600 to $10,000. A 10 KW unit developing 100 Kwh/day, 300 days/year with an operating charge of 20 percent, would supply power at a unit cost of almost 6/Kwh. This compares with the existing charge of 10c/Kwh for fossil fuel based electric power supplied in the urban areas of Bangladesh. The use of small scale hydropower is quite popular in China. It can be used for supplying power for a large number of small industries in the rural areas. "China alone has over 70,000 hydroelectric facilities in operation, most of which are in the 25 Kilowatt or less size range. 7 In addition to conventional small scale hydroelectric turbines that are, in effect, merely miniaturization of the turbines used in large scale hydropower generator, there is a new type of energy-harnessing device which can be used to tap the small elevation differentials and slow moving hydro sites, such as rivers, irrigation canals, and tidal locations. The device which is called a "lift translator" extracts energy from large cross sections of slow moving water, through a continous revolving belt of foils, like a vertical conveyor belt, (Fig. 16).

> Lift translators could tap the energy of rivers having the slope as shallow as a drop of five feet in ten miles. The potential energy tied up in this source has been estimated to be more than $2.5X10^{12}$Kwh. 8

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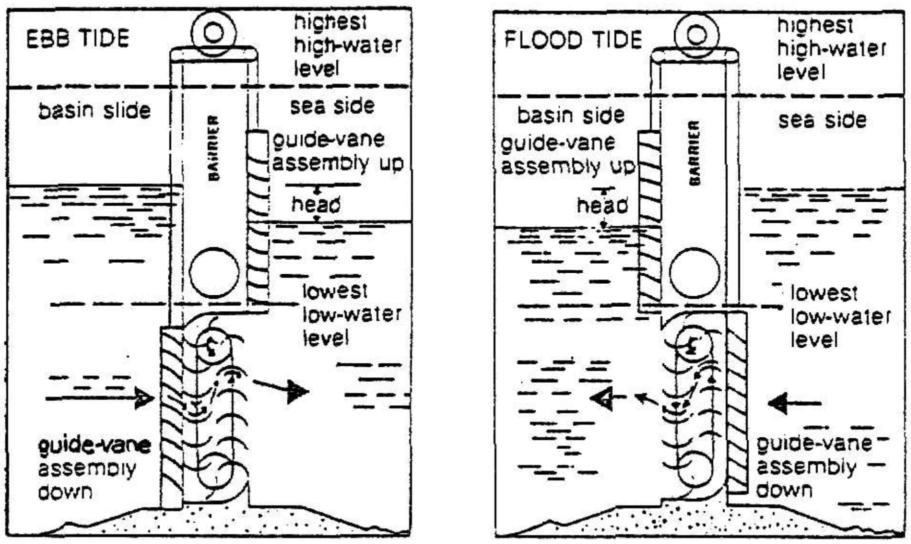
7 Medard Gabel, Energy, Earth and Everyone: Energy Strategies for Spaceship Earth, (New York: Garden City, Anchor Books, 1980.) p. .

8 B. Kocivar, "Lifting Foils," Popular Science, (February 1978) p. 71-73

Tidal "lift translator" has two sets of fixed guide vanes that are raised or lowered, depending on the direction of the tide. These improve the efficiency of the moving vanes by optimizing the angle at which water passes them. In a river or canal setting, only one set of fixed vanes is needed.[8]



This cross section of low-head dam shows barrier (b), stone and sand trap (st), pressure gate (pg), debris screen (ds), and generator (g).[8]

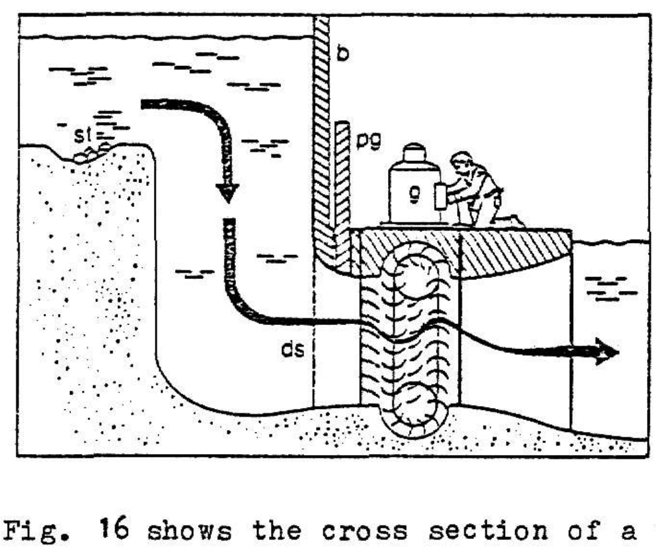


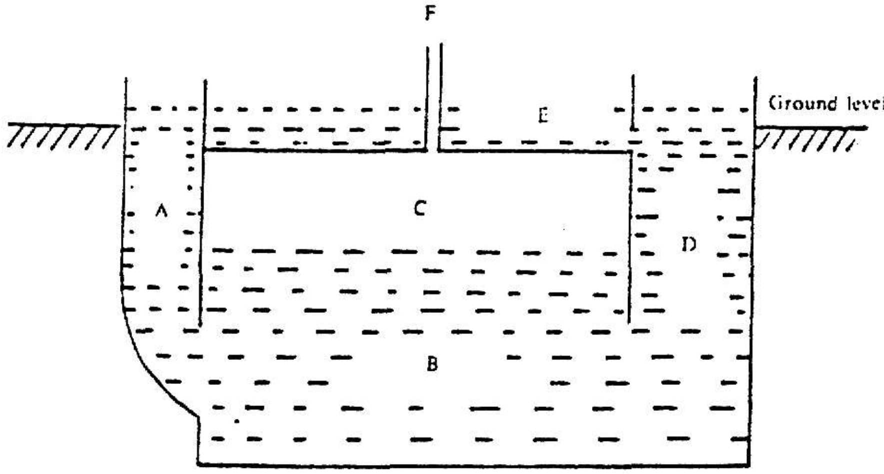
Fig. 16 shows the cross section of a tidal translator.

Since the greater part of the topography of Bangladesh is flat land with very little change in the terrain, building large scale hydroelectric power plants has limited scope. But because of the large numbers of rivers, and the heavy annual rainfall, the water which flows from the mountains of the Himalayas to the sea has tremendous potential energy which could be harnessed by small scale, decentralized hydro power plants.

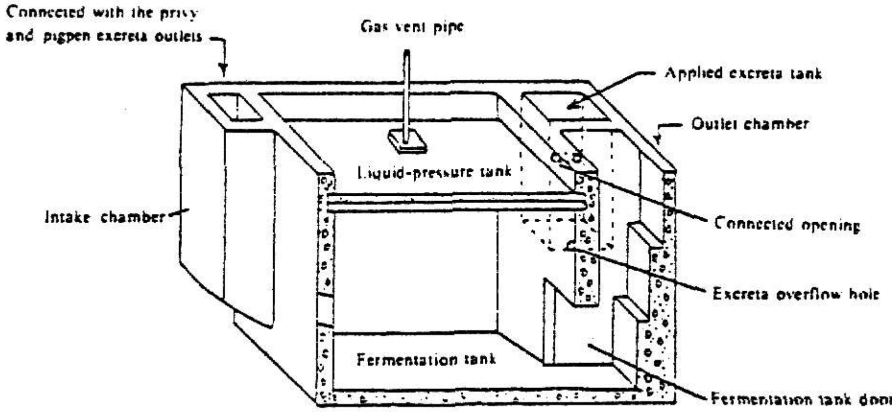
6.7 Biogas technology (Fig. 17)

The generation of methane from human, animal and agricultural wastes is a process increasingly used in the developing countries. The process involves in the fermentation of these materials in the absence of air to produce "Biogas" which contains roughly 60-70 percent methane, 30-40 percent carbon dioxide and a small amount of hydrogen sulfide. When biogas burns, a blue flame is emitted and it produces a large amount of heat energy. It is calculated that 1 cubic meter of biogas will generate 5200-5900 Kcal of heat energy, or light a biogas lamp with a brightness equivalent to 60-100 watt for 5 to 6 hrs. The production of biogas also produces a residue of valuable fertilizers which is rich in plant nutrients. The advantage of biogas is that it is a very good quality fuel. A fermentation tank of $1m^3$ is sufficient to supply fuel for cooking and lighting for a family of five.

In Tanzania it was calculated that the biogas needed for cooking and lighting purposes for a single family would need the animal wastes from four to five cows. This would let the family

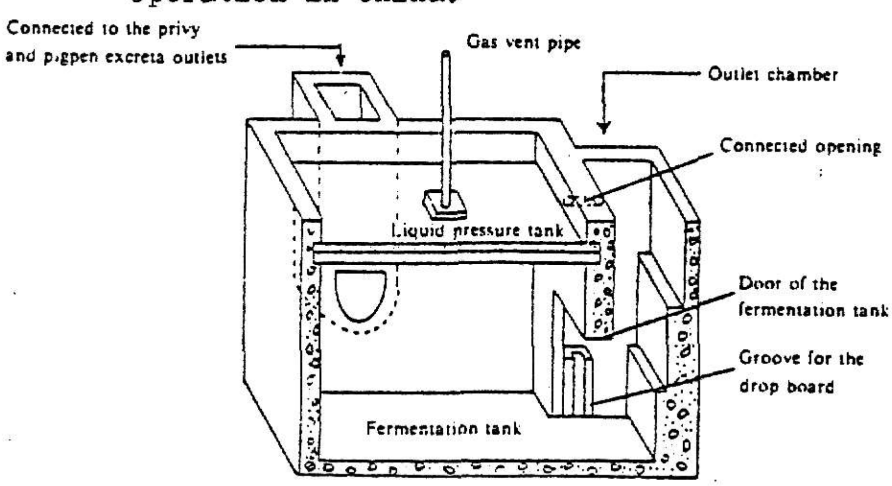


General arrangement of the enclosed biogas plant: A, intake chamber; B, fermentation tank; C, gas storage tank; D, outlet chamber; E, liquid pressure tank; F, gas pipe.



Enclosed three-stage biogas plant with applied excreta tank.

Fig. 17 shows the cross section of a 3-stage biogas plant in operation in China.



Enclosed three-stage biogas plant with drop board.

have 1.4 m^3 of gas for cooking, and 1Kwh/day of electricity for lighting purposes." [9] The heat energy from a single family biogas plant in Tanzania was calculated to cost one-ninth that of the equivalent energy cost of electricity from conventional sources. Biogas is not only suitable for cooking and lighting but it can al also power water pump for irrigation and machinery for crop proce processing. Moreover, the benefits go beyond tha availability of a clean and versatile fuel and the economic advantages are in the conservation of forests and grasses; elimination of insects pests and diseases and, improvement of sanitation and hygienic conditions in the rural areas. In China alone there are an estimated 7 million biogas plants in operation.

Bangladesh has nearly 90 percent of its population in the rural areas dispersed over some 65,000 villages. Along with that there are nearly 15 to 18 million livestock which are used for agricultural purposes. The tremendous amount of animal, human and agricultural wastes are lost because of the lack of biogas technology. In the neighboring country of India there are over 100,000 biogas plants. Community size plants have a great possibility in the villages of Bangladesh.

6.8 Windmill technology

The wind energy that is contained over the subcontinent of India of which Bangladesh is a part is because of the summer monsoon

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[9] Tanzania National Scientific Research Council, Workshop on on Solar Energy for the villages of Tanzania, (BOSTID: 1978) p. 31.

circulation of the Asian region. The monsoon circulation is driven primarily by solar energy through the differential absorption of solar radiation by vast Asiatic land mass on the one hand and the oceanic regions on the other (Fig 18). The Westerly low level monsoon current sweeps over two-thirds of the land mass of the Indian subcontinent. Near the coasts wind tend to be stronger in certain situations due to the additional pressure gradient provided by the thermal contrast between the land and the sea.

The monthly mean wind speeds over the interior of Bangladesh are generally 10 Km.p.h. throughout the year. Consequently, economical utilization of wind power is not possible. But along the coastline near the sea and over the islands in the Bay of Bengal the wind speeds are much higher and are possibly in the range of 15 to 20 Km.p.h. Wind power technology would be quite appropriate in that region of the country and it could very well supplement the solar energy and biogas technology there. In India certain types of windmills have been adapted in the rural areas quite sucessfully. A vertical axis, vertical bladed windmill developed by the Indian Institute of Technology has been found suitable for the rural utility system. A horizontal axis multibladed rotor designed by the Delhi College of Engineering has been operational at low wind speeds and has been useful as sugarcane and oil extractors. In a vertical axis windmill the rotor blades, two or three in number are fixed on a vertical shaft so as to generate a surface of revolution during operation. The principle of operation is based upon the net positive nature of torque

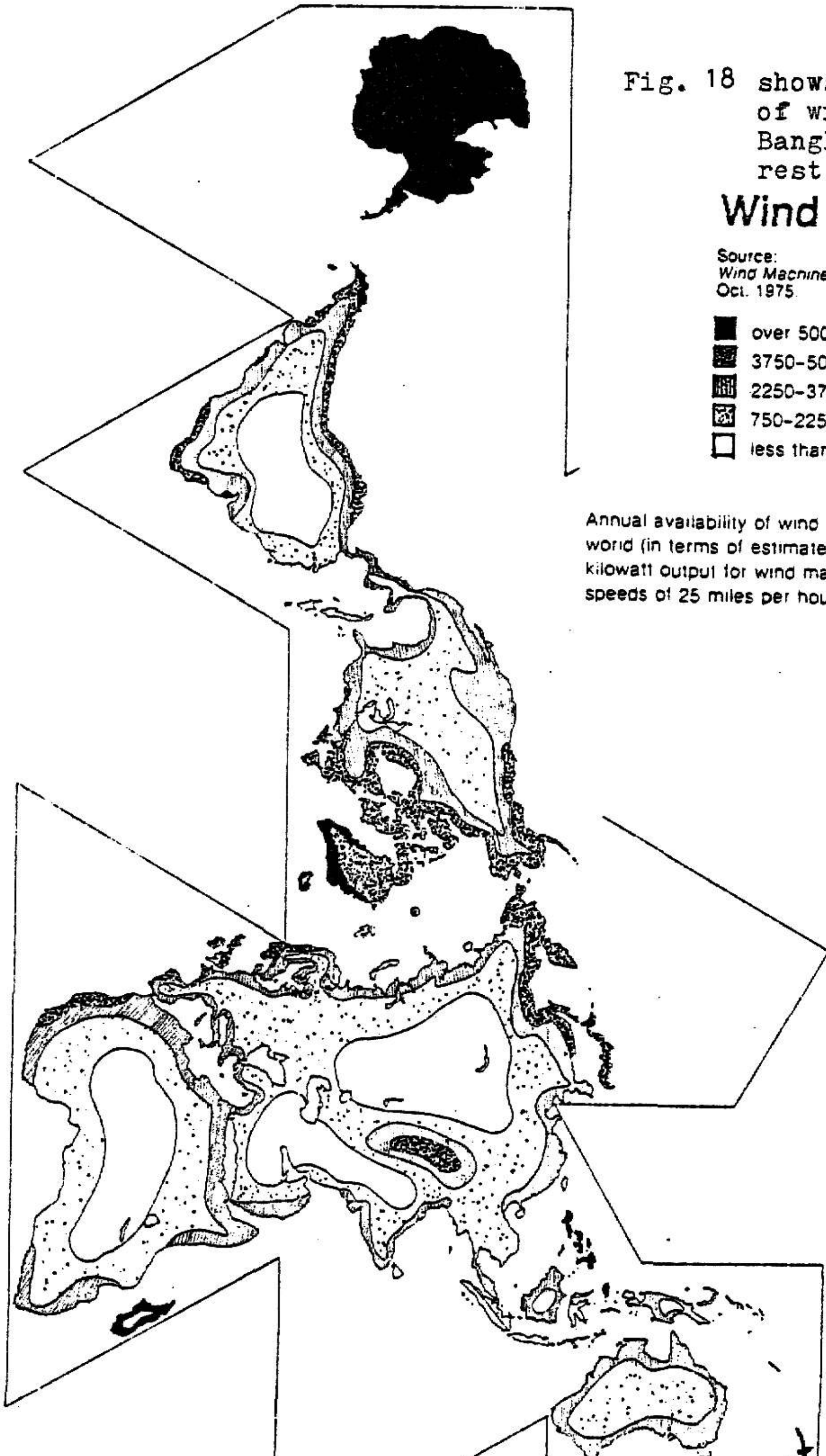


Fig. 18 shows the availability of wind energy over Bangladesh and the rest of the world.

Wind

Source:
Wind Machines, Mitre Corp.
Oct. 1975.

- over 5000 kwh/kw
- 3750-5000
- 2250-3750
- 750-2250
- less than 750

Annual availability of wind energy in different parts of the world (in terms of estimated number of kwh/year per rated kilowatt output for wind machines designed for rated wind speeds of 25 miles per hour).

coeffcient for the blade at varying angles of attack over a complete revolution. The design problems of such a windmill are linked to the choice of the blade-section, number of blades, their orientation and the dimension from the aerodynamic and mechanical point of view. The power produced from a windmill of 4 meter diameter and 6 meter height and subjected to a free stream velocity of 20 km/hr could run a pump to convey a discharge of 18 m^3/hr through a head of 12 meter. The windmill while running at 110 r.p.m. corresponding to a speed ratio of 5 would have an output of 1 Kw, when subjected to a wind speed of 20 Km/hr. At higher wind speeds the windmill tends to generate more power, but the permissible speed of rotation is limited by mechanical considerations (Fig.19). Savonius rotor, 1 meter long and 0.5 meter in diameter has to be installed at mid-height to provide adequate starting torque at speeds as low as 5 Km/hrs and helps to control the maximum speed of the main rotor. Some of the features of the windmill are:

Diameter: 4 meter

Height: 6 meter

Wind Speed: 10 km/hr

Rotation: 110 r.p.m.

Speed ratio: 5.0

Output: 1 Kw.

Efficiency: 40 percent

Details of the rural system:

Water tank: 60 m^3

Daily consumption: 12 m^3

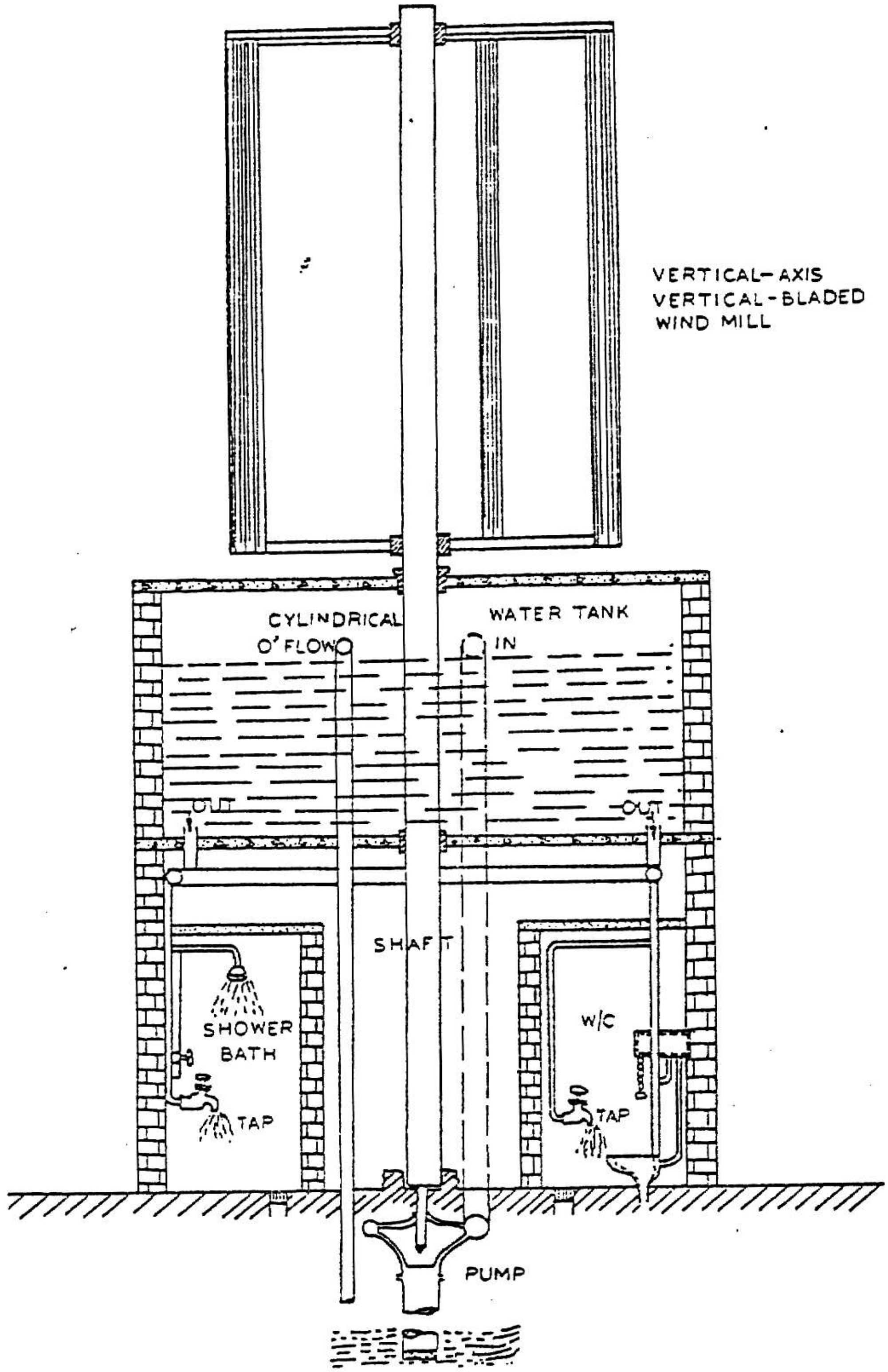


Fig. 19

VERTICAL-AXIS WIND MILL UTILITY SYSTEM FOR RURAL INDIA

Head of Water: 12 m

Shower baths; 4 nos

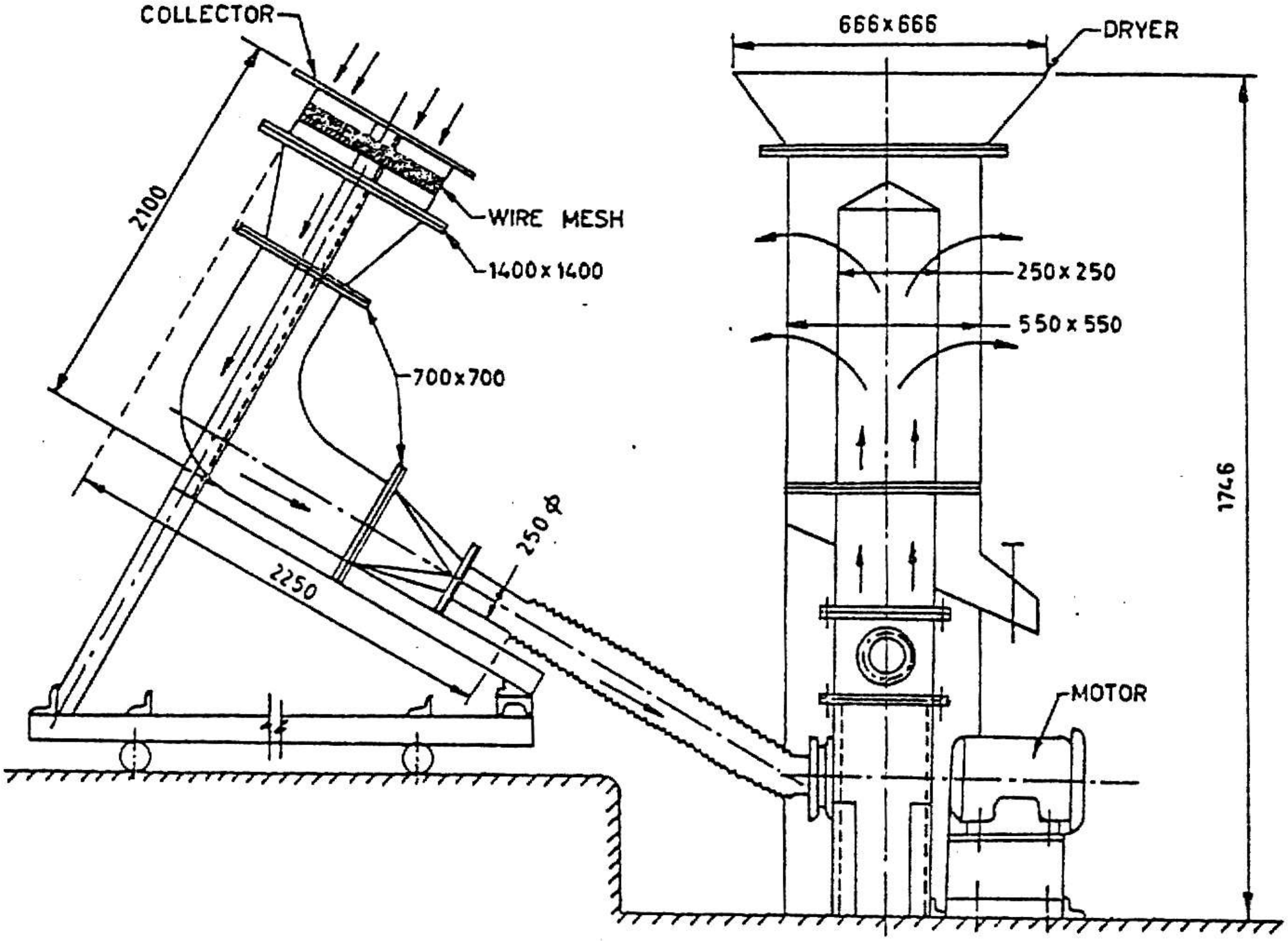
Flush/ w.c.'s : 4

From the Bangladesh point of view, the vertical axis windmill would be a very appropriate technology for the rural areas along the coastline. They would be very useful in pumping water for drinking, washing, grinding and threshing grain and paddy.

6.9 Solar dryer (Fig. 20)

It has been calculated that nearly 25 percent to 33 percent of the grain crops in the developing countries are destroyed each year by pests and molds because of the absence of modern storage and preservation facilities. Bangladesh, which produces nearly 90 percent of it's food grain, suffers from the same problem, and loses yearly at least 20 percent of its food grain. By the use of solar energy, simple low cost small scale systems can be built in the rural areas, which can dramatically increase agricultural productivity. These devices include low cost grain silos which protect the crop from destruction by rodents, birds, insects, and rain; grain driers which reduce losses from mold and equipment for the preservation of meat, fish, vegetables and fruits.

The use of solar energy collectors is a potential means for the effective utilization of radiant energy in grain drying operation operations. Since food grains is very important to the economy of Bangladesh, the benefits of early harvests can be fully obtained if there are proper drying and storage facilities. Crops harvested at high moisture levels should be dried to avoid spoilage



CONTINUOUS SOLAR GRAIN DRYER

Fig. 20 shows the cross section of a solar dryer developed at the Indian Agricultural Institute in New Delhi.

during storage and to preserve the quality and nutritive values. For food grain crops, like paddy harvesting at high moisture levels, drying significantly increases the head rice recovery during milling. The traditional practice of drying has been to expose the crops directly to sunshine in the court yards or in the fields. Besides not being effective during the rainy season, sun drying involves the risk of damage due to weather, birds, rodents, etc. and losses of nutritive value.

"The performance of the experimental solar dryer at the Indian Agricultural Institute in New Delhi has been quite good.[10] It involves the setting up of two south facing solar energy collectors connected to grain holding bins and instrumentation for measurement of solar radiation, relative humidity and air velocity. The roofs of the collectors, 76cmX62cm each were of 22 gauge corrugated galvanised iron sheets blackened with bituminous paint. This is the same type of sheet which is used for building houses in the villages of Bangladesh. The air duct (76cmX62cmX6cm) was provided by means of a plywood plank fitted 6cm below the roof. One end of the duct was connected to a blower assembly housed in an insulated casing. The reamaining two sides of the duct were covered by wooden pieces. The solar heat absorbed by the collectors surface was sucked by the blower and forced through wet grain bed in the holding bins. Drying was accomplished within 8 hours from initial moisture levels as high as 34.9 perecnt down to 15.0 inspite of fluctuating sunshine and humidity. Moreover it was found that due to the orientation of the collectors, at different tilt angles the

[10] F. de Winter and M. Cox, ed., Sun: Mankind's Future Source of Energy, (New York Pergamon Press, 1978) p. 1964

heat absorption varied. A south facing collector at an angle of $28\frac{1}{2}^{o}$ provided the maximum temperature rise in the outlet air. The immense potential for the application of solar dryer in storage and preservation of fresh fruits, vegetables and other foodstuff has proved to be successful, and this device can be applied to the existing conditions of rural Bangladesh.

6.10 Summary

It has been realized all over the world that dependence on fossil fuel for energy requirements has to be reduced, and the only viable alternative is the use of solar energy. India, a developing country with ample conventional energy reserves, have embarked upon the strategy of using renewable resources for the development of its rural economy and raising the standard of living in the villages. For Bangladesh, which has the same climatic factors and a more acute problem, a similar strategy is the most prudent choice. The problems of research, solution and cost factor can be overcome once an active solar energy development policy becomes a reality. To accelerate the economic growth,energy application to the villages of Bangladesh has to be found and provided as capital input and has to be done in the shortest possible time.

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Appendix -A : Lesser Developed Countries (LDC's) of the world.
(Some selected countries)

Low income countries	Population, Mid-1977 (millions)	Level, 1977 (U.S. dollars)
Bhutan	1.2	80
Cambodia	8.4	--
Bangladesh	81.2	90
Lao PDR	3.2	90
Ethiopia	30.2	110
Mali	6.1	110
Nepal	13.3	110
Somalia	3.7	110
Burundi	4.2	130
Chad	4.2	130
Rwanda	4.4	130
Upper Volta	5.5	130
Zaire	25.7	130
Burma	31.5	140
Malawi	5.6	140
India	631.7	150
Mozambique	9.7	150
Niger	4.9	160
Vietnam	50.6	160
Afghanistan	14.3	190
Pakistan	74.9	190
Tanzania	16.4	190
Lesotho	1.3	240
Indonesia	133.5	300
High income countries		
Japan	113.2	5670
France	53.1	7290
Belgium	9.8	7590
Denmark	5.1	8040
Canada	23.3	8460
United States	220.0	8520

Appendix B : Comparison of Radiation received on a horizontal surface for various regions.

Region	Daily average over the year Kwh/m^2
N. Europe	2.4 - 2.8
Sahara Desert	6.4
India/Pakistan/Bangladesh	5.2 - 6.3
Australia	6.1
Japan	3.3 - 4.2
U.S.A. -Northern States	3.9
Southern States	5.8
South Africa (Central)	5.7
Mediterranean Countries	4.3 - 6.0

Appendix - C : Solar Energy

The source of the sun's energy lies deep within its interior. Four million tons of matter are converted into energy every second by the transmutation of hydrogen to helium with subsequent emission of gamma rays. This transmutation involves a multi-nuclear motion which is catalyzed by carbon. Only one percent of the hydrogen in the sun is transformed into helium in a billion years. The gamma rays generated in the sun is not what we receive on earth as light. Much of the heat and light of the sun is due to the collision of the material particles involved in the hydrogen-helium cycle. Gamma radiation has the shortest wave length known (of the order of a hundred-millionth of a millimeter). As these gamma radiation stream outward from the center of the sun, they collide with nuclei and electrons or are scattered in near-collisions. At each event, some of the energy is shared out with the particles struck, and the remaining photons of radiation, having less energy than before, have a longer associated wave length. The radiation leaving the sun and passing out into space is now distributed throughout a wide range of wave lengths with most of the energy between a ten-thousandth of a millimeter and a hundredth of a millimeter. The sun's characteristics are as follows:

Diameter of the sun	1.39×10^6 Km.
Mass of the sun	2200×10^{24} metric tons
Temperature of sun's center	15×10^6 degrees centigrade
Temperature of sun's surface	5×10^3 degrees centigrade

Mean value of solar constant	1.395 Kilowatts per sq. meter
Total radiation continuously intercepted by the outer atmosphere of the earth	173×10^{12} Kilowatts
Total radiation reaching earth's surface	85×10^{12} Kilowatts
Total radiation continuously released by the sun	380×10^{21} Kilowatts

SOLAR ENERGY AND THE DEVELOPMENT OF APPROPRIATE TECHNOLOGY FOR UNDERDEVELOPED COUNTRIES : A CASE STUDY OF A STRATEGY FOR THE DEVELOPMENT OF BANGLADESH

by

MOHAMMAD TANWEER KARIM

B.Arch.,Bangladesh University of Engineering & Technology, 1970

AN ABSTRACT OF A MASTER'S REPORT

submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARCHITECTURE

Department of Architecture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1981

ABSTRACT

The quest for environmentally appropriate technologies is the result of an evolutionary process that began in the 1960's. The preceding post war years were marked by rapid industrial expansion and unprecendented public confidence in the ability of modern technology to provide us with both abundance and happiness. However in the mid 1960's a reaction developed, particularly amongst Western youth and intelligentsia, against the competitive, high consumption, high technological society. This shift in values coinceded with the development of a school of thought, first put forward by Rachel Carson in her book "Silent Spring" and followed by people such as Commoner, Illich, Schumacher, Lovins and others. Their argument was that high technology and rapid economic growth based on fossil fuels and finite resources were destroying and leading to major disruption of the biosphere.

The application of appropriate technology can be multifaceted, be it in agriculture, industry, architecture, planning, etc. In fact the growth of regional architecture relying on local products, labor, culture and microclimate, is an application of appropriate technology.

This report looks at the application of solar energy to the Lesser Developed Countries (LDC's) in creating a development

strategy to be applied to their economy, culture, technology and region. The report does not dwell with either the economic or technical aspect of the application of solar energy but would be more towards stimulating a policy which could be used by these countries. As the basic focus is on Bangladesh the aim of the report is limited in scope. Specifically the aims are to:

1. Focus on the existing energy resources and investigate how solar energy would affect the settlement patterns, urban form and architecture.
2. Study the application of solar energy and its potential from the view point of designing and creating new technologies, urban and social forms.
3. Pinpoint the various case studies from other underdeveloped countries and evaluate them from the development of small scale industry, agriculture, irrigation, rural electrification, usage of surplus labor and the increasing of productivity.

The final format of the evaluation will include written description of the various alternatives and justification of some alternatives for Bangladesh. The objective is to build up a rationale for the application of solar energy and look into the prospects of where it can be started initially in that country. The goal is the reconstituting of a new social order based on self reliant communities, decentralized and sustained by renewable resources. The future land use pattern, bio-regional architecture and urban form would then be the result of symbiosis between society, microclimate, tradition, environment and resources.