Effective Energy Use and Climate Change: Needs of Rural Areas in Developing Countries

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Abstract

The rural energy problem in many developing countries hasn't changed much in the last 20-30 years. Even in those countries that have made particular efforts to "energize" rural areas, a large number of isolated villages still house millions of people lacking enough energy inputs to sustain economic development. But a new threat has been recognized in the past decade or so. It is the threat of global climate change brought about by greenhouse gas emissions, a byproduct of the burning of fossil fuels. A major conflict emerges from the goal of reducing emissions and at the same time providing much more energy for the rural areas of developing countries. This paper starts with a historical review of energy for world agriculture, and continues with discussion of sustainability, private sector support for renewable energy and rural energy policy. It then addresses issues of energy use and climate change and the efforts of the United Nations and most governments to limit undesirable emissions of greenhouse gases resulting from the burning of fossil fuels. It concludes with a discussion of the implications for rural energy in developing countries.

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The Energy Needs of Rural Areas of Developing Countries/Historical Review

Energy is a necessity, not a luxury. The world could not exist as we know it today without controlled use of energy. Humans commonly eat many times as much energy as they can produce. Let us explain. A healthy adult can produce a power output of about 75 W (1/10hp) continuously. Assuming a steady power output of 75 W for a 10-hr day. The work produced (750 watt-hr) is equivalent to 645 kilocalories (kcal). But the muscular work output is only 20-25 percent of the nutrient energy metabolized. Depending on the daily food intake, the ratio of energy in the food eaten to the daily work output may be as high as 15 or 20 to one. Thus, man would starve without supplementing his own physical work output (Stout, et. al. 1979, Chancellor, 2001).

There is no question that energy is necessary to achieve a reasonable quality of life (QOL). Morrison (1978) hypothesized a relationship between QOL and effective energy use as shown in Figure 1. At low levels of energy use (quadrant III) basic need satisfaction is linearly related to energy use. As the amount of energy increases (quadrant II) two paths may be hypothesized. Option A projects a linear relationship between quality of life and energy use; whereas option B suggests an optimum quality of life at a moderately high level of energy use followed by a deterioration in the quality of life for excessively high energy use.

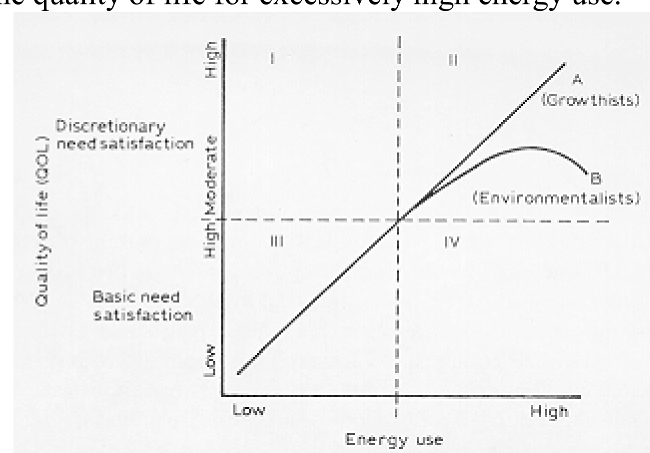

Figure 1. Conflicting growthist and environmental perspectives on the relationship between energy use and the quality of life. Source: Morrison (1978).

The energy-intensive industrialized countries such as the United States are no doubt operating in quadrant II and many cases can be cited where excessive energy use has led to environmental deterioration and subsequently a lower quality of life. Many developing countries, however, are still unquestionably operating in quadrant III, at least insofar as their rural populations are concerned.

Smil and Knowland (1980) in their book entitled, Energy in the Developing World, pointed out that three quarters of mankind live in developing countries where the average consumption of energy per capita is at the level achieved in Europe and North America a century ago. Such low energy usage is accompanied by inadequate diets, poor health care, a low degree of industrialization and too often, socioeconomic malaise. They further state that ... energy is the prime mover of economic growth, but the linkages between energy and development are complex and imperfectly understood. In addition ... there is a need for new policies in developing countries to support serious economic modernization drives. Developing nations need to consume much larger quantities of fossil fuels and electricity and fundamentally change the way in which renewable biomass energies are being depleted.

Another quote comes from Pierre Crosson(1976), an economist with Resources for the Future. He was a member of the U. S. National Academy of Science's team that studied energy in agriculture on a worldwide basis as a part of the world food and nutrition study. He said,

> "To adequately feed the world's expanding population and meet social and economic goals of development, the amount of energy effectively used per person and per hectare in agricultural production, processing and distribution will have to be greatly increased from present levels, especially in the developing countries. Extension of low energy techniques still widely used, that is the man or the woman with the hoe, the bullock, the plow, or the ox cart for transportation to the nearest village, will not produce the surpluses needed to feed the rapidly growing urban populations, often located far from places of agricultural production. Only more energy, vastly more energy than can be provided by man and animals, will do the job. The question is not whether more energy will be needed but what forms it might take."

Roger Revelle (1976), who worked and studied in India, believed that,

> "A considerable increase in energy use will be essential, primarily for three purposes, irrigation, chemical fertilizers, and additional draft power for cultivating fields. The climate and water supply permit growing two crops per year on most on India's arable land, but this will be possible only if facilities for surface and ground water irrigation are greatly expanded, and if abundant nitrogen fertilizers can be made available so that the fields do not have to be left fallow to accumulate nitrogen."

Obviously, more energy is needed if the world is to feed itself. But where will that energy come from? Is the technology available or can it be developed? What are the implications for global climate change? Will the developing countries get their share?

Providing adequate energy for agriculture in the developing countries is one of the world's biggest issues. It's not simply a matter of putting everybody to work with his or her hands.

The developing countries just aren't getting sufficient energy, and unless they do, another serious food deficit is likely to occur. Preventing such an occurrence will present a challenging opportunity for all involved in world agriculture.

There are no easy remedies for the energy dilemmas of developing countries, either on the supply side or in opportunities for conservation. Solutions will likely be composites of a wide variety of supply and demand measures. On the supply side, clearly fossil fuels and conventional hydropower will be the main source of commercial energy for several decades. But global climate change is a recently recognized unknown in the equation (Stout, 1989).

The Challenge of Rural Energy Poverty in the Developing Countries

The conclusions in the above historical references are reconfirmed and reemphasized by recent studies. For example, the World Energy Council and FAO in a recent publication wrote (WEC/FAO, 1999):

> "Three billion people live in rural areas around the world, nearly 90 percent of them in developing countries. The vast majority are overwhelmingly dependent on burning wood, dung and crop residues to provide energy for cooking, heating, and light, often using inefficient technologies. In the poorest rural households, the amount of energy consumed is less than what is needed for a minimum standard of living."

The WEC/FAO report called on governments to better promote renewable and sustainable energy technologies in rural areas. Three recommendations were made:

- Rural energy development must be accorded higher priority
- Rural energy development must be decentralized to place rural people themselves at the heart of planning and implementation
- Rural energy development must be integrated with other measures dealing with agriculture, education, infrastructure and social and political factors.

Agriculture--An Energy Conversion Process

Agriculture is essentially an energy conversion process--the conversion of solar energy through the photosynthetic process to food energy for humans, feed for livestock, fibers and other products. Primitive agriculture involves little more than scattering seeds on the land and accepting the scanty yields that result. Modern agriculture on the other hand, is the application of science and technology to enhance production. An energy subsidy in the form of fossil fuel derived fertilizers and pesticides, fuels for irrigation pumps and farm machinery, or electricity for certain tasks, greatly increases production and helps provide food for a growing world population (Stout, 1989).

Transition to a Sustainable Energy System

A new context for action was proposed by Best, 1992 described as an energy transition. In the developing countries, a transition to a sustainable energy system is urgently needed in most rural areas. This energy transition would be characterized by a move away from the present subsistence –level energy usage levels based on human drudgery and fueled mainly by decreasing firewood resources, to a situation where human and farming activities would be based on sustainable and diversified energy forms. Only by such an energy transition will food production be adequate for growing populations, rural families can attain a higher level of living, and further environmental degradation, mainly caused by poverty, be averted (Best, 1992).

A cynic might say—impossible! Perhaps, but Charles F. Gay, former Director of the U. S. National Renewable Energy Laboratory reported in the July 1996 issue of Solar Today that the cost of renewable energy is falling rapidly as a result of research and development over the past several decades. For example, the cost of wind energy has declined from 50 US cents per kWh in 1980 to around 5 cents in 1995 making wind generated power competitive with electricity produced by coal- or oil-fueled plants in areas with good wind resources. Impressive wind energy projects are being installed in both industrialized (Holland, Denmark, UK, Germany) and developing countries (India, Mexico, China, Argentina). Photovoltaics are already competitive in niche markets throughout the world, with thousands of stand-alone systems now being installed in Brazil, South Africa and many other countries. In addition, ethanol costs have declined from over $1 per liter in 1980 to about 30 cents per liter today, making ethanol fuel nearly competitive with gasoline in some areas. Far from being a "trendy science", Gay says, renewable energy technologies are now backed by more than 15 years of sound, scientific research conducted at some of the world's most advanced laboratories (Gay, 1996).

Former Assistant Secretary of the U. S. Department of Energy, Christine Erwin has said, "Renewable energy is inevitable based on economics. It is inevitable based on the stark reality of meeting human needs. It is also inevitable based on environmental realities." (Gay, 1996).

Major Oil Companies Supporting Renewable Energy

Another hopeful sign is that major oil companies are beginning to take renewable energy seriously and to factor renewables into the energy mix required to meet future demand. For example, Shell International Petroleum Company speculates that perhaps ten different sources will each have a market share between 5 and 15 percent by the year 2060 (Shell 1996). Figure 2, the sustained growth scenario shows use of fossil increasing over the next 30 years, but by 2020/2030, they reach their maximum potential and their use begins to subside. The growing world energy demand is then satisfied by substantial increase in renewable forms of energy, i.e. wind, renewable biomass, solar, geothermal and yet undefined forms labeled "surprise".

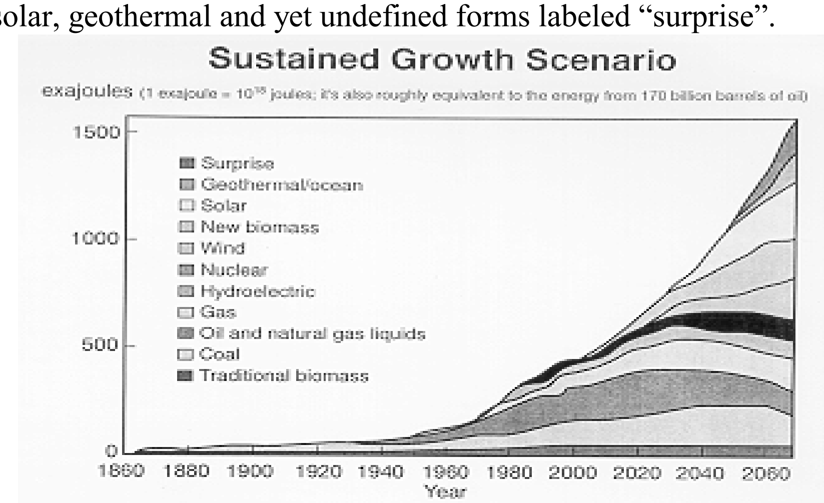

Figure 2. Sustained growth scenario suggesting ten different energy sources by the year 2060 with each having between 5 and 15 percent market share. Source: Shell International (1996) and Gay (1996).

J. S. Jennings, Chairman of the "Shell" Transport and Trading Company spoke to the 16th World Energy Council Congress in Tokyo, October 9, 1995. He said,

> "—I believe we will need as many energy options as possible if we are to give consumers the opportunity to create for themselves the diverse energy supplies which I think they will all seek in such an uncertain world. ---I believe the only prudent energy policy is one of diversity and flexibility. ---During the next 30 years or so most energy demand will be met by the established fossil fuels. ---The new renewable energy resources will become steadily cheaper and thus will be able to expand into new niche markets. ---It is important to remember that all sorts of new energy technologies , including the renewables, have likewise set their sights on achieving acceptable profitability at prices based on $15 per barrel oil. I have no doubt that several of them will achieve this aim in the course of the next 20 years or so."

Another example of major oil companies supporting renewable energy is the formation of Amoseas Indonesia, Inc., owned by Chevron and Texaco. Amoseas operates the Darajet 140 MWe geothermal plant in Indonesia. They estimate the geothermal potential in Indonesia at 20,000 MW (Hadi and Chopin 2001).

The Clean Development Mechanism of the Kyoto Protocol (discussed later in this paper) provides incentives for private companies to assist countries in reducing greenhouse gas emissions resulting from the burning of fossil fuels through an exchange of CO_2 emission rights.

Energy in the World Economy

Energy is a foundation stone of the modern industrial economy. Energy provides an essential ingredient for almost all human activities; it is necessary for cooking and space/water heating, lighting, health, food production and storage, education, mineral extraction, communications, industrial production and transportation. Energy is a powerful engine of economic and social development, and no country has managed to develop much beyond a subsistence economy without ensuring at least minimum access to energy services for a broad section of its population. Throughout the world, the energy resources available to them and their ability to pay largely determine the way in which people live their lives. Nevertheless, it is critical to recognize that what people want are the services that energy provides, not fuel or electricity *per se* (FAO 2000).

Who is in Charge of Energy in Rural Areas?

In many developing countries there is a complete lack of coordination between the rural and the energy sectoral institutions. The rural sector under the Ministry of Agriculture sets agricultural policies and provides for agricultural inputs, commodity programs, and export-import. The rural sector often has little or no contact with the energy sector and does not place a high priority on energy since little commercial energy is used. Rarely are price policies defined with energy needs of the rural population in mind; energy plans and agricultural programs are not linked; energy requirements for agriculture are rarely quantified.

On the other hand, the energy sector is under the Ministry of Energy or whatever it may be called. Energy policies and plans in most countries do not focus on the energy requirements of the agricultural and rural sectors. This is due to the small impact these sectors have on the national energy balance, and because of their meager energy consumption, and because of the inherent difficulty of data collection and management. The low and largely decentralized consumption patterns in rural areas also contribute to this neglect. The Ministry of Energy rarely has representation or a branch in the rural areas. In general the Ministry of Energy is simply not interested in agriculture.

Thus, the Ministry of Agriculture does not include rural energy in its plans and neither does the Ministry of Energy. In fact, no one is in charge of energy in rural areas. This situation has led to a "vacuum" of responsibility and lack of energy programs for rural areas, resulting in scarce allocation of energy resources in rural areas and a low level of energy investments for rural development (Best, 1992). A reduction in the operational role of governments in both agriculture and energy has occurred in recent years. It is necessary to assess the impact of these changes, since they may affect negatively the rate of rural electrification and the rate of utilization of other energy carriers in rural areas. FAO is presently assessing this impact in selected Latin American countries.

Energy Use and the Climate Change

Major Climate Change Events

May 1992	United Nations Framework Convention on climate change (UNFCCC)
May 1994	UNFCCC signed and ratified, entered into force with 186 Parties
1995	First conference of the Parties (COP-1)
December 1997	COP-3 held in Kyoto, Japan developed the Kyoto Protocol: the U.S. Senate unanimously rejected this document.
November 1998	COP-4 held in Buenos Aires
November 2000	COP-6 Part I held in The Hague, Netherlands
March 2001	U.S. Administration (President Bush) declared its opposition to the Protocol.
July 2001	COP-6 Part II held in Bonn, Germany
October 2001	COP-7 held in Marrakech, Morocco

Brief History of the UNFCCC and the Kyoto Protocol (Anon, 2001)

Climate change is considered by many scientists and engineers as one of the most serious threats to the sustainability of the world's environment, human health and well being, and the global economy. The international response to climate change took shape with the development of the UNFCCC. Adopted in 1992, the UNFCCC outlines a framework for action aimed at stabilizing atmospheric concentrations of greenhouse gases at a level that would prevent human-induced actions from leading to "dangerous interference" with the climate system. The UNFCCC entered into force in 1994 and now has 186 Parties. The Conference of the Parties (COP) has met seven times since 1995 to work out the details of an action plan. Following intense negotiations culminating at COP-3 held in Kyoto, Japan in 1997 delegates agreed to a Protocol that commits developed countries and countries making the transition to a market economy to achieve quantified targets for decreasing their emissions of greenhouse gases. The Kyoto Protocol calls for industrialized nations to carry out within one decade, drastic cuts in emissions of greenhouse gases that stem mainly from the burning of fossil fuels. Its enactment, much desired by President Clinton, was rejected by unanimous vote of the U.S. Senate in 1997. Critics say that the Protocol is based on political considerations rather than science or economics.

In March 2001, the Bush Administration declared its opposition to the Protocol, stating it is believed to be "fatally flawed" as it would damage the U.S. economy and that it exempted developing countries from fully participating. The U.S. said it intends to address climate change in a "serious, sensible and science-based manner". The U.S. has been widely criticized for its position, but so far seems firm in its opposition, disregarding the findings put forward by the American scientists who pointed out the importance and relevance of preventive measures regarding climate change. The U.S. has, nevertheless, continued to participate in all discussions relating to commitments under the UNFCCC.

What is the Greenhouse Effect? (Anon, 1994/2001)

In the long term, the earth must shed energy into space at the same rate at which it absorbs energy from the sun. Solar energy arrives in the form of short-wavelength radiation. Some of the radiation is reflected away by the earth's surface and atmosphere. But most of the radiation passes through the atmosphere to warm the earth's surface. The earth gets rid of this energy and sends it back into space in the form of long-wavelength, infra-red radiation.

Most of the infra-red radiation emitted form the earth's surface is absorbed in the atmosphere by water vapor, carbon dioxide, and other naturally occurring "greenhouse gases".

By increasing the atmosphere's ability to absorb infra-red energy, our greenhouse gas emissions are disturbing the way the climate maintains a balance between incoming and outgoing energy. The result is global warming.

Energy Impact on Global Environment (Anon, 1994/2001)

Background

The 1992 United Nations Framework Convention on Climate Change (UNFCCC) is one in a series of recent agreements through which countries around the world are banding together to deal with changes in the global environment. Climate change is nothing new. One theory is that dinosaurs became extinct as a result of climate change. Later, sea levels fell and humans moved across land bridges from Asia to the Americas. During the ice age glaciers covered much of the northern regions. People often suffer as a result of these natural climate changes.

Now human behavior, largely attributed to the burning of fossil fuels, seems to be changing the global climate again. The future is uncertain, but if current predictions prove correct, the climatic changes over the coming century will be larger than any since the dawn of human civilization.

We are changing the balance of gases that form the earth's atmosphere. This is especially true of such key "greenhouse gases" as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Water vapor is the most important greenhouse gas, but human activities do no affect it directly. These naturally occurring gases make up less than one tenth of one percent of the total atmosphere, which consists mostly of oxygen (21 per cent) and nitrogen (78 per cent). But greenhouse gases are vital because they act like a blanket around the earth. Without this natural blanket the earth's surface would be as much as 30 C colder than it is today.

The problem is that human activity is making the blanket "thicker". For example, when we burn coal, oil and natural gas we spew huge amounts of carbon dioxide into the air. When we destroy forests the carbon stored in the trees escapes to the atmosphere. Other basic activities, such as raising cattle and planting rice, emit methane, nitrous oxide and other greenhouse gases. If emissions continue to grow at current rates, the UNEP/WMO predicts that atmospheric levels of carbon dioxide will double from pre-industrial levels during the 21st century. The most likely result will be a "global warming" of 1.5 to 4.5 C over the next 100 years.

The effect of global warming is hard to predict and highly controversial because the global climate is a very complex system. Global warming may lead to shifts in wind and rainfall patterns and higher sea levels that threaten low-lying coastal areas and islands. In a world that is increasingly crowded and under stress, these extra pressures could lead directly to famines and other catastrophes.

The text of the UNFCCC was adopted by the United Nations on 9 May 1992 and entered into force on 21 May 1994 following the required signatures and ratification.

Key Actions of UNFCCC

1. It recognizes that there is a problem. This is a significant step. A specific course of action is still being debated.
2. It sets an "ultimate objective" of stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous human-induced interference with the climate system.
3. It directs that the level of greenhouse gases be achieved within a timeframe sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

If the Consequences are Uncertain, Why Do Anything?

Some experts say that climate change is a threat to mankind. Responding to the threat is expected to be expensive, complex and difficult. Other experts even question whether there is any problem at all. And the debate continues about the seriousness of the threat and who will suffer most. But if the nations of the world wait until the consequences are clear, it may be too late to act.

Some possible effects of climate change:

1. Regional rainfall patterns may change. The evapo-transpiration rate may speed up. This means it may rain more, but the rain would evaporate faster, leaving soils drier during critical parts of the growing season. New droughts may reduce supplies of fresh water to

the point where there are major threats to public health. And with global water resources already under severe strain from rapid population growth and expanding economic activity, the danger is clear.

2. Agricultural zones may shift toward the poles. Increased summer dryness, drought and heat waves may reduce temperate zone crop yields, while northern areas such as Canada and southern areas such as Argentina may benefit.
3. Melting glaciers and thermal expansion of sea water may raise sea levels, threatening low-lying coastal areas and small islands.

It's Not Fair

There is a fundamental unfairness to the climate change problem that stresses already uneasy relations between the rich and poor nations of the world. Highly industrialized countries with high standards of living are mostly responsible for the rise in greenhouse gases. By exploiting high energy-density fossil fuels they created their wealth in part by pumping large quantities of greenhouse gases into the atmosphere long before the consequences were understood. Developing countries now fear being told that they should curtail their own fledgling industrial activities – that the atmosphere's safety margin has been used up. This is especially a problem for rural areas of developing countries which so desperately need more energy to increase food production and improve their standard of living.

Because burning of fossil fuels is the leading cause of climate change, there will be growing pressure on all countries to reduce the amounts of coal and oil they use. This can be a great opportunity for renewable sources of energy such as solar in all its forms, geothermal and so on.

How the UNFCCC Responds

1. It puts the greatest share of the responsibility for battling climate change on the rich countries because the largest share of emissions originate in the developed countries. The Kyoto Protocol calls for the industrialized countries to carry out, within one decade, drastic cuts in the emission of greenhouse gases that stem mainly from the burning of fossil fuels. And this led to the unanimous rejection of the Kyoto Protocol by the U.S. Senate in 1997 and repudiation by the Bush Administration in 2001.
2. The UNFCCC recognizes that the poorer nations have a right to economic development.
3. It acknowledges the vulnerability of poorer countries to the effects of climate change.

If the Whole World Starts Consuming More, Can the Planet Stand the Strain?

As human population continues to grow, the demands on the environment increase. Rapidly increasing numbers of people want to live better lives...more and better food, more and cleaner water, more electricity, refrigerators, automobiles, houses and apartments and so on. There are already problems in growing and distributing enough food and catching enough fish.

Global warming is a particularly ominous consequence of mankind's insatiable appetite for natural resources. During the last century or so, we have burned massive stores of coal, oil and natural gas, finite reserves that took millions of years to accumulate. The practice of burning fossil fuels so rapidly has upset the natural balance of the carbon cycle.

There seems to be only one answer – renewable energy based on widespread exploitation of abundant various forms of solar energy. People must have energy to live the good life. There is no shortage of energy, but we must learn to shed our over-dependence on finite supplies of fossil fuels which produce undesirable emissions when burned.

Sustainable development is the key to human salvation. Somehow, mankind must learn how to alleviate poverty for huge and growing numbers of people without destroying the natural environment on which all human life depends. Somehow a way has to be found to develop economically in a fashion that is sustainable over a long period of time. Unfortunately, the international community is a lot further along in defining the challenges posed by sustainable development than it is in figuring out how to solve them.

Additional UNFCCC Responses

The UNFCCC calls for developing and sharing environmentally sound technologies and know-how. Technology will clearly play a major role in dealing with climate change. Agricultural engineers and other engineers and scientists are working diligently to find practical ways to use clean sources of energy such as solar power in all its forms. Technology can make industrial processes more efficient, water purification more viable, agriculture more productive with reduced use of fossil fuels. As such technology becomes more cost effective and widely available, it must somehow be shared by richer and poorer countries where the need is so great. COP has established an expert group on technology transfer. Six key technical issues have been identified: environmental impact assessments, public participation, baselines, small-scale projects under the clean development mechanism (CDM), certified emissions reduction (CER) transactions, and mechanisms' eligibility and the verification procedures that may be used.

The Convention emphasizes the need to educate people about climate change. The world – the climate and all living things – is a closed system; what we do today has consequences that will eventually come back to affect us.

Human behavior will have to change. But the details are hard to prescribe and predict. Progress has been made in defining the problem. Now the challenge is to develop solutions that are technically feasible, cost effective and fair and equitable for all mankind. That is a tall order, but the future of mankind may well depend on our success.

Key Provisions of the Kyoto Protocol

The Protocol calls for industrialized nations to carry out drastic cuts in the emission of greenhouse gases. Annex I Parties (industrialized countries) committed themselves to reducing their overall emissions of six greenhouse gases by at least 5% below the 1990 levels over the period from 2008 to 2012 with specific targets varying from country to country. The Protocol also provided the basis for three mechanisms to assist Annex I Parties in meeting their national targets in a cost-effective manner – 1) an emission trading system, 2) joint implementation (JI) of emissions reductions projects between Annex I Parties and 3) a Clean Development Mechanism (CDM) to encourage joint projects between Annex I and non-Annex I (developing countries)

Parties. JI and CDM are "flexibility mechanisms" that allow an investor or donor country to fund projects that reduce greenhouse gas emissions in a host country.

Joint Implementation (JI)

In JI, a donor country will be an industrialized country with emissions targets, whereas a host country will be an economy in transition (both Annex I countries). The credits that will be transferred under JI are called emission reductions units (ERU).

Clean Development Mechanisms (CDM)(Lee, 2001)

The purpose of the CDM is to assist Parties not included in Annex I (developing countries) in achieving sustainable development and Annex I Parties in achieving compliance with their emissions limitations. Under the CDM, developing countries will benefit from projects resulting in emissions reductions and sponsoring parties in Annex I may use the emission reductions accruing from such projects to contribute to their compliance. Certified Emission Reductions (CER) resulting from CDM projects are based on:

a. Voluntary participation by each Party
b. Real, measurable and long-term benefits related to mitigation of climate change
c. Reduction in emissions in addition to any that would occur in the absence of a project.

Industry seems to have taken a positive stance toward CDM. For example, the Regional Association of Oil and Natural Gas Companies in Latin America and the Caribbean (ARPEL) considers the CDM to be a key provision of the Kyoto Protocol (ARPEL, 2001). CDM needs to be carefully designed to ensure that common objectives of reducing greenhouse gas emissions, technology development and transfer, and other benefits to numerous partners, stakeholders and businesses in the Region, are achieved. ARPEL believes that the CDM, if developed and implemented properly, will help build partnerships not only between member companies, but also between the oil and gas industry with other industries, governments and non-governmental organizations in the Region to reduce greenhouse gas emissions at the lowest cost while promoting new investments, development and transfer of technology, best practices and sustainable development.

Table 1 summarizes the potential and benefits of companies participating in CDM.

Table 1: Potential Benefits and Concerns from Different Perspectives[1]

Perspective	Potential Benefits	Potential Concerns
Non-Annex I countries	• Access to "cleaner" more advanced technology. • Foreign direct investment.	• Bureaucracy of the CDM Executive Board, CDM processes. • Inequities among non-Annex I

[1] Adapted by Arthur Lee from "Attracting Northern Private Sector Investment for Greenhouse Gas Reduction in the South" (Texaco), Bjorn Stigson, President of World Business Council for Sustainable Development (Lee, 2001).

	• Jobs, new skills to workforce, etc. • Improved living standards. • Improved access to energy. • Biodiversity and community improvements.	countries – competition for projects. • Hidden costs for the host country. • Verification standards should not be different from those of JI and emissions trading. • A non-equitable price system of carbon certificates. • That CDM becomes a non-tariff barrier.
Annex I countries	• Cost-effective means to comply with Kyoto targets. • Leverage in access to new markets. • Show commitment to climate change issue. • Engage developing countries in participation of Kyoto Protocol.	• Bureaucracy and transaction costs. • Uncertainties surrounding many issues. • Emissions trading and joint implementation credits may be easier to obtain than doing CDM projects due to the perceived bureaucracy, potential high costs, and uncertainties.
Non-Annex I businesses	• May provide business opportunities in many sectors. • Provide new partnership possibilities with Annex I companies. • Savings in energy	• Threat from Annex I businesses leveraging into domestic markets.

	costs. • Image and reputation. • Access to training, technical, and financial support.	
Annex I businesses	• May be a cost-effective way to get emission reduction credits. • Market opportunities. • Partnerships with non-Annex I businesses. • CO2 offset business opportunities. • Image and reputation.	• Uncertainties with respect to "additionality" and "sustainable development." • High transaction costs and hidden costs.

Implications for Rural Areas of Developing Countries

Renewable Energy from Agriculture and Forestry (FAO, 2000)

Access to adequate and affordable energy is one of the prerequisites for equitable socio-economic development. Biofuels from agriculture and forestry can contribute toward a more gender balanced rural employment and income, and can strengthen rural livelihood systems to attain better levels of food security. New and/or improved technologies for bioenergy utilization as an industrial energy source at competitive market prices can contribute to an improvement of rural livelihood systems.

The negative implications of this approach, i.e. the potential threat to forests if fuelwood is used indiscriminately or in an unsustainable way, deterioration of watersheds, loss of soil fertility and biodiversity, must be carefully weighed against the potential benefit.

Possible conflicts with other land use requirements must also be resolved. Land availability is often seen as a constraint to the production of energy crops. With many people in developing countries still undernourished, it is a justified concern. Food production should receive top priority. However, food production is a complex socio-economic, political and cultural issue that goes beyond the earth's carrying capacity to grow food crops. If farmers are given the opportunity through economic incentives, land tenure rights and capital investments, they will be able to produce more food (and energy crops) than has been the case so far. Synergies in terms of job opportunities, enhanced rural infrastructure and market promotion might arise when both food and energy crops are produced. The "bringing back to production" of degraded or marginal lands can be an added benefit of bioenergy plantations.

Clearly, the replacement of fossil fuels through increased utilization of biofuels produced in a sustainable manner, can contribute towards a cleaner environment, reduction of greenhouse gas emissions and mitigation of climate change.

Climate Change Mitigation (FAO, 2000)

The threat of climate change is principally an energy-related problem. Current energy systems are based on the combustion of fossil fuels, which account for 75% of the world's primary energy supply. Bioenergy produced from agriculture and forestry can contribute to climate change mitigation by CO_2 substitution. Biomass offers a carbon-neutral source of energy that is renewable on a short time scale and hence could provide an attractive means of climate change mitigation. Key aspects that should be considered are:

- The technical potential of CO_2 emissions substitution by using bioenergy,
- Technologies that are needed to exploit bioenergy, including their availability, cost-effectiveness and environmental impacts
- Economics
- Institutional, legal and organizational structures needed to deliver

The Role of Bioenergy in Climate Change Mitigation (FAO, 2000)

Exploitation and commercialization of biomass through modern technology offers significant cost-effective opportunities for meeting emissions reduction targets while providing additional economic and social benefits. Bioenergy provides a sustainable use of accumulated carbon and can be used as a substitute for fossil fuels.

Biomass is bulky and has a low energy-density compared with fossil fuels and also may have a high moisture content which reduces the net energy available. Economics and energy collection costs may be substantial, but biomass has the potential to generate employment and to assist economic growth in rural areas.

Many complex issues are raised in shifting from petroleum fuels to biomass, e.g., the possible competition with food production, economics of biomass utilization, net energy output, and technical aspects of conversion to liquid or gaseous fuels and so on. New species may be needed to meet the demands of crops to be grown as biomass fuels.

Estimating the potential of biomass to offset CO_2 emissions is complex because of the many variables involved such as crop productivity, energy conversion efficiencies, and substitution factors. FAO developed a simplified approach using the product of (cropland area) times (crop yield) to estimate the carbon offset potential. This calculation should be scaled by an energy substitution factor to account for conversion efficiencies.

Table 2. Potential CO_2 mitigation via fossil carbon offsets using biomass (FAO/Netherlands, 1999)

	Land area	Net C yield	Net C offset	Energy	C emissions

	(Mha)	(tC/ha/year)	(Mt/year)	Substitution efficiency	reduction (MtC/year)
Dedicated energy crops: Temperate areas	26-73	5-9	130-660	0.65-0.75	80-490
Dedicated energy crops: tropical areas	41-57	6-12	250-680	0.65-0.75	160-510
Temperate shelter-belts	13-26	2-4	30-100	0.5-0.7	10-50
Tropical agro-forestry	41-65	3-6	120-390	0.5-0.7	50-200
Crop residues			350-460	0.6-0.7	210-320
Total			**880-2290**		**510-1570**

Table 2 summarizes the potential of biomass for CO_2 mitigation (16). Forestry and energy crops have the potential to reduce emissions by 510 – 1570 million tonnes carbon per year, which is equivalent to between 8 and 27 percent of the current global consumption of fossil fuels. It is important to keep in mind that these estimates are the "technical achievable potential" and do not take into account economic, policy or institutional constraints that might reduce the opportunities for Carbon offsets.

Exploiting the Potential of Biomass (FAO, 2000)

Table 3 summarizes the advantages and disadvantages of using biomass for fuel. CO_2 mitigation may tip the balance in favor of biomass fuels especially if Global Environmental Facility (an international financing mechanism) funding or CERs obtained through the Clean Development Mechanism can be used to offset investment cost.

Table 3: Exploiting the Potential of Biomass (FAO, 2000)

Advantages	Disadvantages
Biomass is a stored fuel, and can provide a demand responsive supply of energy.	Present-day biomass technology has a poor cost-effectiveness compared with most conventional energy supply options.
Biomass is a flexible fuel feedstock, and the only renewable energy source, which can be converted into convenient secondary forms, namely solid, liquid or gaseous fuels.	The ownership of modern biomass technology is largely in industrialized countries, and would require technology transfer for its exploitation in developing countries.
Biomass is a carbon neutral energy source, renewable over a relatively short time-frame.	The long-term effects of biomass exploitation, through dedicated energy crop plantations, on soil quality, fertility and biodiversity may be adverse.

Fuel production, collection and supply are labor intensive, which can be an attractive social benefit in rural areas.	Biomass plantations may conflict with other land uses in competition for high quality land.
When developed as part of an integrated approach to wasteland restoration and rural economic development, biomass offers additional environmental, social and economic benefits in rural areas.	A fuel supply chain and a ready market for energy output, with robust and secure contracts must be in place.

Greenhouse Gas Emissions from Agriculture in Canada

Agricultural engineers and other agricultural scientists are just beginning to address the issue of GHG emissions from agricultural operations. A recent example is the study by Dyer and Desjardins (2001) that reports on a computer model for simulating farm power requirements, machine hours, and fuel consumption. Emissions of GHG were estimated for plowing, disking, and seeding operations in the spring, along with fall harvesting and cultivation for weeds, spreading of manure and spraying for pests. They estimated GHG emissions at 5.8 Tg from both diesel and gasoline for farm field operations in Canada. They point out the need for policy analysts to relate tillage practices that maintain the soil carbon sink to fossil fuel emissions from farm fieldwork.

Concluding Remarks

The threat of global climate is uncertain and controversial, but it seems prudent to take the threat seriously and to utilize renewable energy as much as economically and technically feasible to replace and augment fossil fuels. Some relevant factors include:

- Fossil fuels are valuable because of their high energy density, but supplies are finite
- Future generations will need diminishing supplies of fossil fuels
- The burning of fossil fuel generates large quantities of CO_2 and other greenhouse gases
- Renewable energy avoids the problem of GHG emissions
- Renewable energy exploitation can provide jobs in rural areas of developing countries and thus increase rural incomes

The Quality of Life (QOL) in rural areas of developing countries is severely limited by lack of energy needed to produce food, process it and deliver it to markets; to improve the economy, provide jobs, adequate housing, clothing, health care, transport and all the other ingredients for a higher QOL.

A fundamental conflict arises from the need for more energy in the rural areas of developing countries and the goal of reducing fossil fuel consumption with the accompanying GHG emissions. Utilization of renewable energy may be a partial solution. One form of renewable energy, biomass can be grown as an energy crop, thus increasing rural income and providing more energy for rural use. The transition from fossil fuel to biomass is complex and involves many technical, policy and economic issues. Careful study and much additional research will be required to develop sustainable and cost-effective systems for production, collection, storage, conversion, distribution and marketing of biomass for fuel.

The Kyoto Protocol is designed to provide mechanisms and incentives for reduction of GHG emissions. Agricultural engineers and other engineers and scientists should be familiar with the Kyoto Protocol and use the opportunity to serve humans everywhere by developing practical and cost-effective renewable energy systems to replace and augment fossil fuels. The future of mankind may depend on our success.

References

Anon. (2001). Earth Negotiations Bulletin. 12(176):1-15 www.iisd.ca/climate/cop6bis/ 161 Portage Avenue East, 6th Floor, Winnipeg, Manitoba R3B 0Y4 CANADA.

Anon. (1994) (Modified 2001). Beginners Guide to the Convention. UNEP/WMO Information Unit on Climate Change. UNEP/IUC, Geneva Executive Center, Box 356, 1219 Chatelaine, Switzerland.

Anon. (1992). Kyoto Protocol to the United Nations Framework Convention on Climate Change (Full Text). 17pp. www.unfccc.de/resource/docs/convkp/kpeng.html.

ARPEL. (2001). ARPEL's Approach to the Clean Development Mechanism. Regional Association of Oil and Natural Gas Companies in Latin America and the Caribbean. Montevideo, Uruguay. www.arpel.org

Best, G. (1992). Energy, environment and sustainable rural development. Journal World Energy Council. p. 90-99.

Chancellor, W. J. (2001). Personal communication.

Crosson, Pierre (1976). Interdependencies between food sector and non-food sector activities with respect to energy resources and environment. National Academy of Sciences. Washington, D.C. World Food and Nutrition Study, Subgroup 10 B. 30pp.

Dyer, J. A. and R. L. Desjardins, (2001). In Press. Simulated Farm Field Work, Fossil Fuel Energy Consumption and Related Greenhouse Gas Emissions in Canada. Submitted to Canadian Biosystems Engineering.

FAO/Netherlands. (1999). Conference on the Multifunctional Character of Agriculture and Land. Maastricht, September.

Food and Agriculture Organization of the United Nations (FAO) (2000). The Energy and Agriculture Nexus. Environment and Natural Resources Working Paper No. 4. Rome. 84pp.

Gay, C. F. (1996). Energy and the environment: creating new industries. Solar Today. 10(3):16-19.

Hadi, J. and C. Chopin (2001). Increased Energy Efficiency through Sharing of Geothermal Energy for Agricultural Direct Uses in Indonesia—AMOSEAS Perspective. Proc. of Int'l Conf. on Integrated Renewable Energy for Regional Development. Bali, Indonesia. Aug. 28-31.

Lee, Arthur (2001). ARPEL's Approach to the Clean Development Mechanism. Society of Petroleum Engineers Paper SPE 69442.

Morrison, D. E. (1978). Equity impacts of some major energy alternatives, In Energy Policy in the United States: Social and Behavioral Dimensions. ed. S. Warkov, Praeger, New York, pp.164-193.

Revelle, Roger (1976). Energy use in rural India. Science 192:969-975.

Shell International (1996). The evolution of the world's energy systems. London; Shell International, Ltd.

Smil, V. and W. E. Knowland, (Eds.) (1980). Energy in the Developing World. Oxford University Press, Oxford, U.K. 386 pp.

Stout, B. A. (1989). Handbook of Energy for World Agriculture. Elsevier Applied Science. London. 504 pp.

Stout, B. A., C. A. Myers, A. Hurand and L. W. Faidley. (1979). Energy for World Agriculture. FAO Agriculture Series No. 7. FAO, Rome. 286 pp.

WEC/FAO. (1999). The Challenge of Rural Energy Poverty in the Developing Countries. World Energy Council/Food and Agriculture Organization of the United Nations. Gustavo.Best@FAO.org