Renewable Energy Use and Energy Efficiency – A Critical Tool for Sustainable Development

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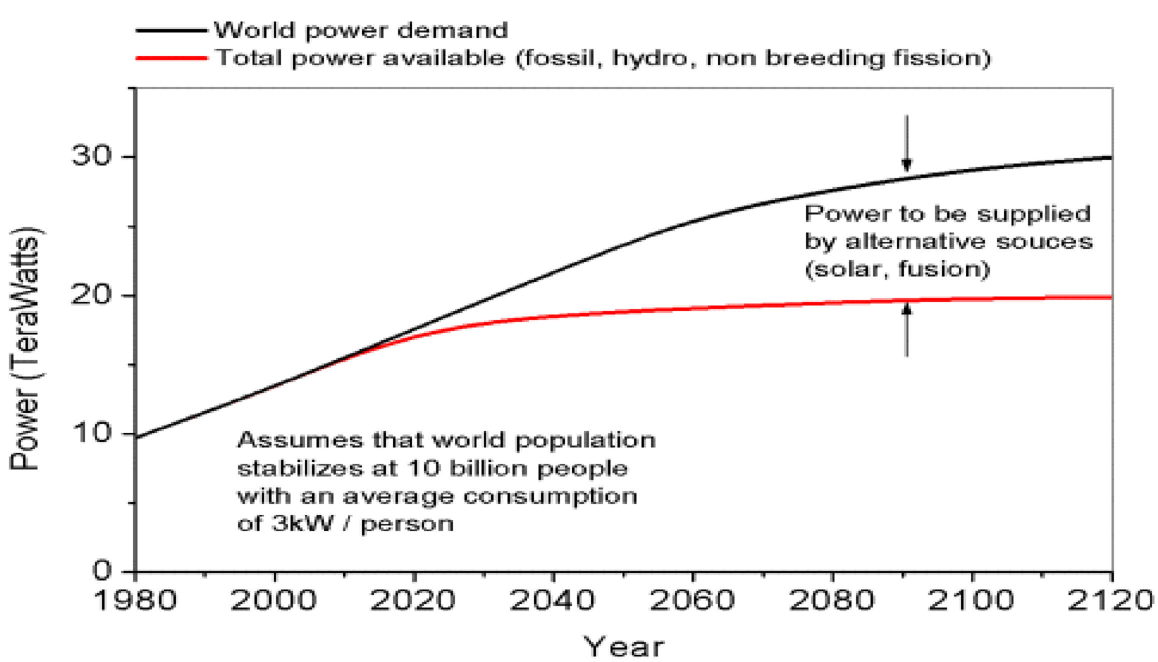
1. Introduction

Energy efficiency and renewable energy are the "twin pillars" of a sustainable energy policy. Both strategies must be developed concurrently in order to stabilize and reduce carbon dioxide emission (American Council for an Energy-Efficient Economy, 2007). Efficient energy use is essential to slowing the energy demand growth so that rising clean energy supplies can make deep cuts in fossil fuel use. If energy use grows too rapidly, renewable energy development will chase a receding target. Likewise, unless clean energy supplies come online rapidly, slowing demand growth will only begin to reduce total carbon emissions; a reduction in the carbon content of energy sources is also needed. A sustainable energy economy thus requires major commitments to both efficiency and renewable (American Council for an Energy-Efficient Economy, 2007).



Estimates of the world energy use indicate that the demand for energy, by the middle of the 21st Century, may significantly exceed the energy supplied by conventional sources. The shortfall in energy becomes larger after the depletion of fossil fuels, about 100 years in the future. Source: http://www.plasma.inpe.br

Renewable energy is energy which comes from natural resource such as sunlight, winds, plants growth, rain, tides and geothermal heat which are naturally replenished.

The first law of thermodynamic says that the total amount of energy on our planet remains constant. The second law states that as forms of energy are expended they become less easily available. That is entropy: the slow winding down of available energy (Jacobson, 2009).

- First law of thermodynamics: *A change in the internal energy of a closed thermodynamic system is equal to the difference between the heat supplied to the system and the amount of work done by the system on its surroundings.*

The first law of thermodynamics asserts the existence of a state variable for a system, the internal energy, and tells how it changes in thermodynamic processes. The law allows a given internal energy of a system to be reached by any combination of heat and work. It is important that internal energy is a variable of state of the system whereas heat and work change the state of the system.

The first law observes that the internal energy obeys the principle of conservation of energy, which states that energy can be transformed (changed from one form to another), but cannot be created or destroyed.

- Second law of thermodynamics: *Heat cannot spontaneously flow from a colder location to a hotter location.*

The second law of thermodynamics is an expression of the universal principle of decay observable in nature. The second law is an observation of the fact that over time, differences in temperature, pressure, and chemical potential tend to even out in a physical system that is isolated from the outside world. Entropy is a measure of how much this process has progressed. The entropy of an isolated system which is not in equilibrium will tend to increase over time, approaching a maximum value at equilibrium.

When coal, gas or oil is burnt, it rapidly converts a relatively easily available and concentrated source of energy into a much less available form: dispersed exhaust gases.

A high concentrated energy source, built up over millions of years quickly gone up in smoke. So, burning fossil fuels is high-entropy way of using energy.

Using renewable energy however merely taps into a natural flow of energy, sunlight, moving water, wind, biological or geothermal process. These are part of natural cycles of highs and lows. Their energy is truly renewable as it remains available to the same degree and is not depleted any more than it otherwise would be by using it.

Renewable energies include wind, ocean, wave and tides, solar, biomass, rivers, geothermal (heat of the earth) etc. They are renewable because they are regularly replenished by natural processes and are therefore in endless supply (Fatona, 2009; Jacobson, 2009). They also can operate without polluting the environment. Technologies have been developed to harness these energies and such technologies are called renewable energy technologies (RET) or sometime also called "Clean technologies" or "Green energy" (Pearce et al, 1989). Because renewable energy are constantly being replenished from natural sources, they have security of supply, unlike fossil fuels, which are negotiated on the international market and subject to international competition, sometimes may even resulting in wars and shortages. They have important advantages which could be stated as follows:-

1. Their rate of use does not affect their availability in future, thus they are inexhaustible.
2. The resources are generally well distributed all over the world, even though wide spatial and temporal variations occur. Thus all regions of the world have reasonable access to one or more forms of renewable energy supply.

3. They are clean and pollution-free and therefore are sustainable natural form of energy.
4. They can be cheaply and continuously harvested and therefore sustainable source of energy.

Unlike the nuclear and fossil fuel plants which belong to big companies, governments, or state around enterprises, renewable energy can be set up in small units and is therefore suitable for community management and ownership. In this way, value from renewable energy projects can be kept in the community.

Transition from fossil fuels to renewable energy will not result in net job losses or cause harm to the economy. Renewal energy technologies (RETs) are labour intensive, and can produce more jobs than fossil fuel or nuclear industries. When RETs are properly integrated into national development plans and implemented, they can substantially reduce greenhouse gas emissions and simultaneously increase employment (Pearce et al, 1989). Moreover, it will also enhance energy security by reducing reliance on oil, preserve the competitiveness of energy, lead to savings for consumers and provide transitional assistance to workers in negatively affected industries and communities. With the right approach the interest of working families and the environment can come together (Pearce et al, 1989).

2. What is energy efficiency?

Energy efficiency means improvement in practice and products that reduce the energy necessary to provide services like lightning, cooling, heating, manufacturing, cooking, transport, entertainment etc. Energy efficiency products essentially help to do more work with less energy. Thus, the efficiency of an appliance or technology is determined by the amount of energy needed to provide the energy service. For instance, to light a room with an incandescent light bulb of 60w for one hour requires 60w/h. A compact florescent light bulb would provide the same or better lighting at 11w and only use 11w/h. This means that 49w (82% of energy) is saved for each hour the light is turned on.

Making homes, vehicles, and businesses more energy efficient is seen as a largely untapped solution to addressing the problems of pollution, global warming, energy security, and fossil fuel depletion. Many of these ideas have been discussed for years, since the 1973 oil crisis brought energy issues to the forefront. In the late 1970s, physicist Amory Lovins popularized the notion of a "soft energy path", with a strong focus on energy efficiency. Among other things, Lovins popularized the notion of negawatts—the idea of meeting energy needs by increasing efficiency instead of increasing energy production (Krech, 2004).

Lovins viewed the energy problem not one of an insufficient supply of oil and other conventional energy sources, but rather as one of inefficient energy use, coupled with lack of development of renewable energy sources. Lovins argued that conventional energy production was both energy intensive and a source of substantial pollution. With his reformulation of the energy problem, "environmentalists criticized plans for large-scale energy developments, especially those relying heavily on nuclear power".

The "soft energy path" assumes that energy is but a means to social ends, and is not an end in itself. Soft energy paths involve efficient use of energy, diversity of energy production methods (matched in scale and quality to end uses), and special reliance on co-generation and "soft energy technologies" such as solar energy, wind energy, bio-fuels, geothermal energy, wave power, tidal power, etc (Nash, 1979).

Soft energy technologies (appropriate renewables) have five defining characteristics. They (1) rely on renewable energy resources, (2) are diverse and designed for maximum effectiveness in particular circumstances, (3) are flexible and relatively simple to understand, (4) are matched to end-use needs in terms of scale, and (5) are matched to end-use needs in terms of quality (Nash, 1979).

Residential solar energy technologies are prime examples of soft energy technologies and rapid deployment of simple, energy conserving residential solar energy technologies is fundamental to a soft energy strategy. Active residential solar technologies use special devices to collect and convert the sun's rays to useful energy and are located near the users they supply. Passive residential solar technologies involve the natural transfer (by radiation, convection and conduction) of solar energy without the use of mechanical devices.

Lovins argued that besides environmental benefits, global political stresses might be reduced by Western nations committing to the soft energy path. In general, soft path impacts are seen to be more "gentle, pleasant and manageable" than hard path impacts. These impacts range from the individual and household level to those affecting the very fabric of society at the national and international level.

Lovins recognised that major energy decisions are always implemented gradually and incrementally, and that major shifts take decades. A chief element of the soft path strategy is to avoid major commitments to inflexible infrastructure that locks us into particular supply patterns for decades.

Lovins explained that the most profound difference between the soft and hard paths — the difference that ultimately distinguishes them — is their different socio-political impact. Both paths entail social change, "but the kinds of social change for a hard path are apt to be less pleasant, less plausible, less compatible with social diversity and freedom of choice, and less consistent with traditional values than are the social changes which could make a soft path work".

Moving towards energy sustainability will require changes not only in the way energy is supplied, but in the way it is used, and reducing the amount of energy required to deliver various goods or services is essential. Opportunities for improvement on the demand side of the energy equation are as rich and diverse as those on the supply side, and often offer significant economic benefits.

In most places, a lot of energy is wasted because industries, power companies, offices and households use more energy than is actually necessary to fulfill their needs. The reasons is because they use old and inefficient equipment and production processes; buildings are poorly designed; and because of bad practices and habits. With energy efficiency practices and products, nations can save over 50% of the energy being consumed. Using energy more efficiently would:

1. Reduce electricity bills.
2. Leave more energy available to extend energy supply to all parts of the population.
3. Increase the efficiency and resilience of the economy – including reduced reliance on oil and thus improve balance of payments.
4. Improve industries competitiveness internationally.
5. Minimize the building of new power stations and thus free up capital for other investments like health and welfare.

6. Reduce the negative environmental and human health impacts from energy production and use.
7. Increase employment through interactions e.g. in industry, housing, transport.

3. Renewable energy and sustainable development

The World Summit on Sustainable Development (WSSD) in Johannesburg in 2002 recognized the important role of energy for reaching millennium development goals. Access to affordable, reliable and sustainable energy is essential to sustainable development (Hasna, 2007). An adequate solving of energy problems will contribute to achieving progress across all pillars of sustainable development; social, economic and environmental and in meeting the UN millennium goals. Although there are no MDGs on access to energy, WSSD recognized that inadequate access to energy is both a cause and an effect of poverty and recommended the following:

"*Take joint actions and improve efforts to work together at all levels to improve access to reliable and affordable energy service for sustainable development sufficient to facilitate the achievement of the Millennium Development Goals, including the goal of halving the proportion of people in poverty by 2015, and as a means to generate other important services that mitigate poverty, bearing in mind that access to energy facilitates the eradication of poverty*" .

"Sustainable development" has been defined best by the Brundtland Commission as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Hasna, 2007). Adequate and affordable energy supplies has been key to economic development and the transition from subsistence agricultural economics to modern industrial and service oriented societies. Energy is central to improved social and economic well being and is indispensable to most industrial and commercial wealth organization. It is the key for relieving poverty, improving human welfare and raising living standards. But however essential it may be for development, energy is only a means to an end. The end is good health, high living standards, a sustainable economy and a clean environment.

Much of the current energy supply and use, based as it is, on limited resources of fossil fuels, is deemed to be environmentally unsustainable. There is no energy production or conversion technology without risk or waste. Somewhere along all energy chains - from resource extractions to the provision of energy service – pollutants are produced, emitted or disposed of, often with severe health and environmental impacts (Dasgupta, 2001; Fatona, 2009). Combustion of fossil fuels is chiefly responsible for urban air pollution, regional acidification and the risk of human – induced climate change (Dasgupta, 2001; Fatona, 2009). Achieving sustainable economic development on a global scale will requires the judicious use of resources, technology, appropriate economic incentives and strategic policy planning at the local and national levels. It will also require regular monitoring of the impacts of selected policies and strategies to see if they are furthering sustainable development or if they should be adjusted (Arrow et al, 2004).

When choosing energy fuels and associated technologies for the production, delivery and use of energy services, it is essential to take into account economic, social and environmental consequences (Ott, 2003; Wallace, 2005). There is need to determine whether current energy use is sustainable and, if not, how to change it so that it is. This is the purpose of energy indicators, which address important issues within three of the major dimensions of sustainable development: economic, social and environmental.

4. Energy indicators for sustainable development

4.1 Social dimension

SOC1: Share of households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy
- Households (or population) without electricity or commercial energy, or heavily dependent on non-commercial energy
- Total number of households or population

SOC2: Share of household income spent on fuel and electricity
- Household income spent on fuel and electricity
- Household income (total and poorest 20% of population)

SOC3: Household energy use for each income group and corresponding fuel mix
- Energy use per household for each income group (quintiles)
- Household income for each income group (quintiles)
- Corresponding fuel mix for each income group (quintiles)

SOC4: Accident fatalities per energy produced by fuel chain
- Annual fatalities by fuel chain
- Annual energy produced

4.2 Economic dimension

ECO1: Energy use per capita
- Energy use (total primary energy supply, total final consumption and electricity use)
- Total population

ECO2: Energy use per unit of GDP
- Energy use (total primary energy supply, total final consumption and electricity use)
- GDP

ECO3: Efficiency of energy conversion and distribution
- Losses in transformation systems including losses in electricity generation, transmission and distribution

ECO4: Reserves-to-production ratio
- Proven recoverable reserves
- Total energy production

ECO5: Resources-to-production ratio
- Total estimated resources
- Total energy production

ECO6: Industrial energy intensities
- Energy use in industrial sector and by manufacturing branch
- Corresponding value added

ECO7: Agricultural energy intensities
- Energy use in agricultural sector
- Corresponding value added

ECO8: Service and commercial energy intensities
- Energy use in service and commercial sector
- Corresponding value added

ECO9: Household energy intensities
- Energy use in households and by key end use

- Number of households, floor area, persons per household, appliance ownership

ECO10: Transport energy intensities

- Energy use in passenger travel and freight sectors and by mode
- Passenger-km travel and tonne-km freight and by mode

ECO11: Fuel shares in energy and electricity

- Primary energy supply and final consumption, electricity generation and generating capacity by fuel type
- Total primary energy supply, total final consumption, total electricity generation and total generating capacity

ECO12: Non-carbon energy share in energy and electricity

- Primary supply, electricity generation and generating capacity by non-carbon energy
- Total primary energy supply, total electricity generation and total generating capacity

ECO13: Renewable energy share in energy and electricity

- Primary energy supply, final consumption and electricity generation and generating capacity by renewable energy
- Total primary energy supply, total final consumption, total electricity generation and total generating capacity

ECO14: End-use energy prices by fuel and by sector

- Energy prices (with and without taxes or subsidies)

ECO15: Net energy import dependency

- Energy imports
- Total primary energy supply

ECO16: Stocks of critical fuels per corresponding fuel consumption

- Stocks of critical fuel (e.g. oil and gas)
- Critical fuel consumption

4.3 Environmental dimension

ENV1: Greenhouse gas (GHG) emissions from energy production and use, per capita and per unit of GDP

- Population and GDP

ENV2: Ambient concentrations of air pollutants in urban areas

- Concentrations of pollutants in air

ENV3: Air pollutant emissions from energy systems

- Air pollutant emissions

ENV4: Contaminant discharges in liquid effluents from energy systems

- Contaminant discharges in liquid effluents

ENV5: Soil area where acidification exceeds critical load

- Affected soil area
- Critical load

ENV6: Rate of deforestation attributed to energy use

- Forest area at two different times
- Biomass utilization

ENV7: Ratio of solid waste generation to units of energy produced

- Amount of solid waste
- Energy produced

ENV8: Ratio of solid waste properly disposed of to total generated solid waste

- Amount of solid waste properly disposed of
- Total amount of solid waste

ENV9: Ratio of solid radioactive waste to units of energy produced

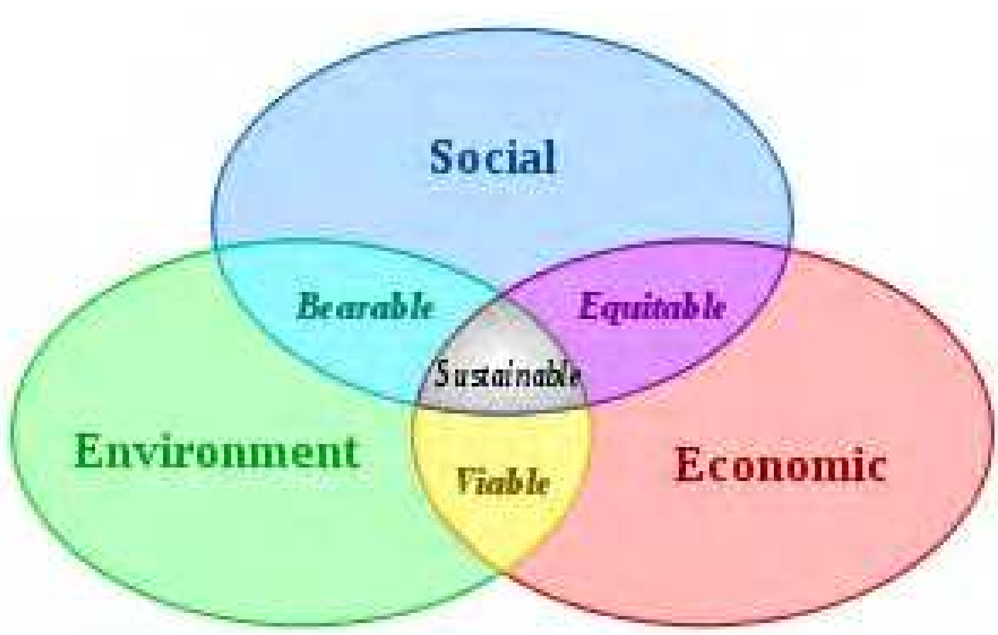
- Amount of radioactive waste (cumulative for a selected period of time)
- Energy produced

ENV10: Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste

- Amount of radioactive waste awaiting disposal
- Total volume of radioactive waste

5. Dimensions of sustainable development

Sustainable development is essentially about improving quality of life in a way that can be sustained, economically and environmentally, over the long term supported by the institutional structure of the country (Adams, 2006; Chambers et al, 2000).



Scheme of sustainable development: at the confluence of three constituent parts

Social dimension:- Availability of energy has a direct impact on poverty, employment opportunities, demographic transition, pollution and health. Social equity is one of the principal values underlying sustainable development, involving the degree of fairness and inclusiveness with which energy resources are distributed, energy systems are made accessible and pricing schemes are formulated to ensure affordability. Energy should be available to all at a fair price.

The use of energy should not damage human health, but rather should improve it by improving conditions. Yet the production of non renewable has the potential to cause injury or disease through pollution generation or accidents. A social goal is to reduce or eliminate these negative impacts. The health indicators have the sub theme of safety, which covers accident fatalities caused by the extraction, conversion, transmission / distribution and use of energy. Oil rigs and particularly coal mines are subjected to accidents that injure, main or kill people. Oil refineries and power stations may release emissions into the air that cause lung or respiratory diseases.

Economic dimension:- Modern economics depend on a reliable and adequate energy supply, and developing countries need to secure this as a prerequisite for industrialization. All sectors of the economy – residential, commercial, transport, service and agriculture demand modern energy services. These services in turn foster economic and social development at the local level by raising productivity and enabling local income generation. Energy supply affects jobs, productivity and development.

The prices of end-use energy by fuel and sector have obvious economic importance. Efficient energy pricing is a key to efficient energy supply and use and socially efficient levels of pollution abatement.

Addressing energy security is one of the major objectives in the sustainable development criteria of many countries. Interruptions of energy supply can cause serious financial and economic issues. To support the goals of sustainable development, energy must be available at all times, in sufficient quantities and at affordable prices. Secure energy supplies are essential to maintain economic activities and providing reliable energy services to society.

Environmental dimension:- The production, distribution and use of energy create pressures on the environment in the household, workplace and city and at the national, regional and global levels. The environmental impacts can depend greatly on how energy is produced and used, the fuel mix, the structure of the energy systems and related energy regulatory actions and pricing structure. Gaseous emissions from the burning of fossil fuels pollute the atmosphere. Large hydropower dams cause silting. Both the coal and nuclear fuel cycles emit some radiation and generate waste. And gathering firewood can lead to deforestation and desertification Daly & Cobb, 1990; Hilgenkamp, 2005).

Water and land quality are important sub-themes of the environmental dimensions. Land is more than just physical space and surface topography; it is in itself an important natural resource, consisting of soil and water essential for growing food and providing habitat for diverse plant and animal communities. Non – renewable energy activities may result in land degradation and acidification that affect the quality of water and agricultural productivity.

Land is also affected by energy transformation processes that often produce solid wastes, including radioactive wastes, which require adequate disposal. Water quality is affected by the discharge of contaminants in liquid effluents from energy systems, particularly from the mining of non renewable energy resources, which is environmentally unsustainable (Daly & Cobb1990; Hilgenkamp, 2005).

Environmental sustainability is the process of making sure current processes of interaction with the environment are pursued with the idea of keeping the environment as pristine as naturally possible based on ideal-seeking behavior.

Consumption of renewable resources	State of environment	Sustainability
More than nature's ability to replenish	Environmental degradation	Not sustainable
Equal to nature's ability to replenish	Environmental equilibrium	Steady state economy
Less than nature's ability to replenish	Environmental renewal	Environmentally sustainable

An "unsustainable situation" occurs when natural capital (the sum total of nature's resources) is used up faster than it can be replenished. Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally (Barbier, 2007). Inherently the concept of sustainable development is intertwined with the concept of carrying capacity. Theoretically, the long-term result of environmental degradation is the inability to sustain human life. Such degradation on a global scale could imply extinction for humanity.

6. Conclusion

There is an intimate connection between energy, the environment and sustainable development. A society seeking sustainable development ideally must utilize only energy resources which cause no environmental impact. Clearly, a strong relation exists between energy efficiency and environmental impact since, for the same services or products, less resource utilization and pollution is normally associated with increased energy efficiency.

Sustainable energy is the provision of energy that meets the needs of the present without compromising the ability of future generations to meet their needs. Sustainable energy sources are most often regarded as including all renewable energy sources, such as hydroelectricity, solar energy, wind energy, wave power, geothermal energy, bio-energy, and tidal power. It usually also includes technologies that improve energy efficiency.

Renewable energy technologies are essential contributors to sustainable energy as they generally contribute to world energy security, reducing dependence on fossil fuel resources and providing opportunities for mitigating greenhouse gases. As such, sustainable energy promotes sustainability. Sustainability, here, is twofold, as it constitutes self-sustenance and the ability to foster sustainable development.

By being self-sustaining the energy source is in essence limitless. Solar energy, wind energy, geothermal energy, hydropower and biomass are all self-sustaining. They all have sources that cannot be depleted. These energy sources allow for the conservation of other energy sources, like trees that would have been used for charcoal production. Using these "renewable" energies also encourages the protection of the environment which traditional energy sources have helped to destroy. The use of some traditional energy sources, like oil and charcoal, the Natural Resources Conservation Authority (NRCA) reported "carries with it a number of environmental problems, such as water and air pollution and the contamination of soils." Utilizing sustainable energy would then lead to the conservation of the environment which would eventually lead to a development which meets the needs of the present, without compromising the ability of future generations to meet their own needs. In other words, sustainable energy use leads to sustainable development.

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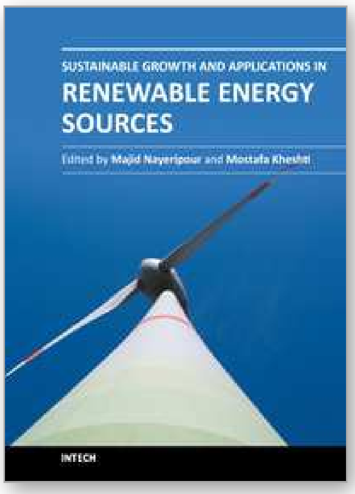

Sustainable Growth and Applications in Renewable Energy Sources

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Worldwide attention to environmental issues combined with the energy crisis force us to reduce greenhouse emissions and increase the usage of renewable energy sources as a solution to providing an efficient environment. This book addresses the current issues of sustainable growth and applications in renewable energy sources. The fifteen chapters of the book have been divided into two sections to organize the information accessible to readers. The book provides a variety of material, for instance on policies aiming at the promotion of sustainable development and implementation aspects of RES.