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Energy, environment and sustainable development

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Abstract

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 (e.g. which release no emissions to the environment). However, since all energy resources lead to some environmental impact, it is reasonable to suggest that some (not all) of the concerns regarding the limitations imposed on sustainable development by environmental emissions and their negative impacts can be in part overcome through increased energy efficiency. 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. Presented in this paper are (i) a comprehensive discussion of the future of energy use and the consequent environmental impacts in terms of acid precipitation, stratospheric ozone depletion and the greenhouse effect, (ii) some solutions to current environmental issues in terms of energy conservation and renewable energy technologies, (iii) some theoretical and practical limitations on increased energy efficiency, (iv) discussions of the relations between energy and sustainable development, and between the environment and sustainable development, and an (v) illustrative example. In this regard, a number of issues relating to energy, environment and sustainable development are examined from both current and future perspectives. In addition, some recommendations are drawn from the results we present for the use of energy scientists and engineers and policy makers, along with the anticipated effects.

1. Introduction

Civilization began when people found out how to use fire extensively. They burned wood and obtained sufficiently high temperatures for melting metals,

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extracting chemicals, and converting heat into mechanical power, as well as for cooking and heating. During burning, the carbon in wood combines with O_2 to form CO_2, which is then absorbed by plants and converted back to carbon for use as a fuel again. Since wood was unable to meet the fuel demand, the industrial revolution began with the use of fossil fuels, e.g. oil, coal and gas. Using such fuels has increased the CO_2 concentration in air leading to the beginning of global warming. Despite several warnings in the past about the risks of greenhouse-gas emissions, significant actions to reduce environmental pollution were not taken and now many researchers have concluded that global warming is occurring. During the past two decades, the public has become more aware and researchers and policy makers have focused on this and related issues by considering energy, environment and sustainable development.

World population is expected to double by the middle of the 21st century [1], and economic development will almost certainly continue to grow. Global demand for energy services is expected to increase by as much as an order of magnitude by 2050, while primary energy demands are expected to increase by 1.5–3 times [1]. Simultaneously, concern will likely increase regarding energy-related environmental concerns such as acid precipitation, stratospheric ozone depletion and global climate change (the greenhouse effect). These observations and others demonstrate that energy is one of the main factors that must be considered in discussions of sustainable development.

Several definitions of sustainable development have been put forth, including the following common one: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [2]. Many factors contribute to achieving sustainable development. One of the most important is the requirement for a supply of energy resources that is fully sustainable [3–5]. Increased energy efficiency is also important. The material presented in this paper is intended to apply to both industrialized and developing countries.

While environmental issues in general have been influencing developments in the energy sector for some time, climate change poses an altogether different kind of challenge. Problems such as acid precipitation could be dealt with in part by administrative measures, such as vehicle exhaust standards or emission limits for power stations, which affect comparatively small numbers of economic actors. Technical fixes with a relatively limited scope, such as fitting flue gas cleaning equipment or catalytic converters, could contain the problem. However, emissions of greenhouse gases are so dispersed that it is not possible to take this local and relatively small approach in dealing with climate change. The nature of the problem demands a more comprehensive energy policy response which influences the actions of energy consumers and producers in all countries.

In this paper, environmental issues such as acid precipitation, stratospheric ozone depletion, and the greenhouse effect are discussed, particularly as they relate to energy, environment and sustainable development. An illustrative example is presented.

2. Environmental issues

The most important forms of global pollution problems are as follows:

- acid precipitation
- stratospheric ozone depletion, and
- the greenhouse effect (climate change).

2.1. Acid precipitation

Acids produced by the combustion of fossil fuels (e.g. in smelters for non-ferrous ores, industrial boilers, and transportation vehicles) can be transported over great distances through the atmosphere and deposited via precipitation on the earth on ecosystems that are exceedingly vulnerable to damage from excessive acidity. This acid precipitation was found to be mainly attributable to emissions of SO_2 and NO_x [6]. A schematic representation of the formation, distribution, and impact of acid precipitation is shown in Fig. 1. These pollutants have caused only local concerns related to health in the past. However, as awareness of their contribution to the regional and transboundary problem of acid precipitation has grown, concern is now also focusing on other substances such as volatile organic compounds (VOCs), chlorides, ozone and trace metals that may participate in the complex set of chemical transformations in the atmosphere resulting in acid precipitation and the formation of other regional air pollutants. The well known effects of acid precipitation include: acidification of lakes, streams and ground waters, resulting in damage to fish and aquatic life; damage to forests and agricultural crops; and deterioration of materials, e.g., buildings, metal structures and fabrics. Some energy-related activities

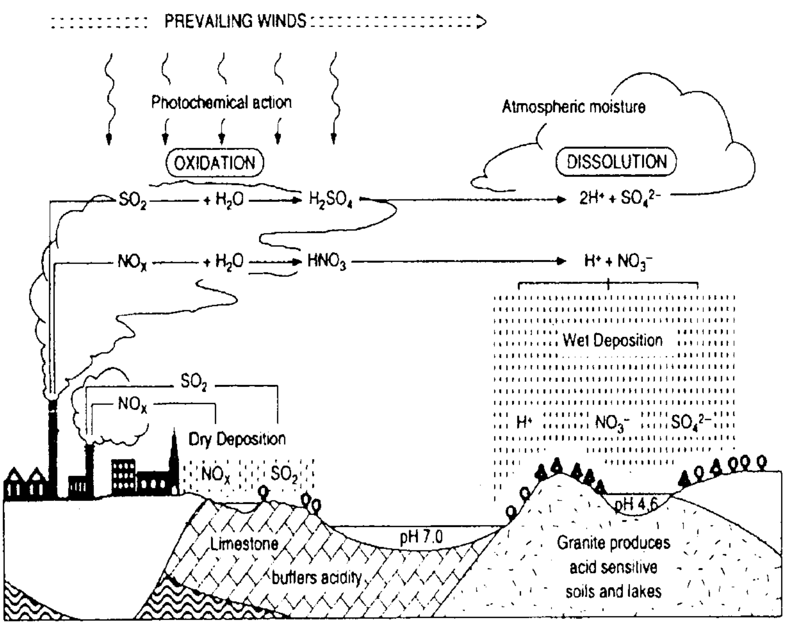

Fig. 1. Processes leading to acid rain (source: Perman et al. [18]).

are major source of acid precipitation. For example, electric power stations, residential heating and industrial energy use account for 80% of SO_2 emissions, with coal use alone accounting for about 70% of SO_2 emissions. Another source of acid precipitation is sour gas treatment which produces H_2S that then reacts to form SO_2 when exposed to air. Road transport is an important source of NO_x emissions, accounting for 48% of the total emissions in OECD countries [7]. Most of the remaining NO_x emissions are due to fossil fuel combustion in stationary sources. Additionally, VOCs are generated by a variety of sources, and comprise a large number of diverse compounds. Countries in which the energy-related activities mentioned in the previous paragraph occur widely are likely to be significant contributors to acid precipitation. The largest contributors in the world are the United States, countries from the former Soviet Union and China [1].

2.2. Stratospheric ozone depletion

It is well known that the ozone present in the stratosphere, roughly between altitudes of 12 and 25 km, plays a natural, equilibrium-maintaining role such as absorption of ultraviolet (UV) radiation and absorption of infrared radiation [6]. A global environmental problem is the distortion and regional depletion of the stratospheric ozone layer which was shown to be caused by chlorofluorocarbons (CFCs), halons (chlorinated and brominated organic compounds) and N_2O emissions. Ozone depletion in the stratosphere can lead to increased levels of damaging ultraviolet radiation reaching the ground, causing increased rates of skin cancer, eye damage and other harm to many biological species. Fig. 2 exhibits a schematic representation of the

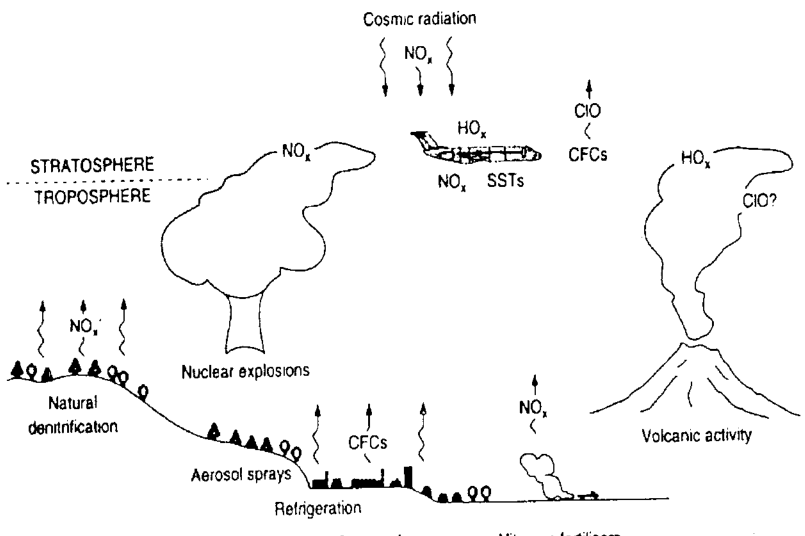

Fig. 2. Schematic representation of ozone-depleting sources (source: Perman et al. [18]).

sources of natural and anthropogenic ozone depleters. Energy-related activities are only partially (directly or indirectly) responsible for the emissions which lead to stratospheric ozone depletion. Though such energy activities such as fossil fuel and biomass combustion account for 65–75% of anthropogenic N_2O emissions, CFCs [6], which are used in air conditioning and refrigerating equipment as refrigerants and in foam insulation as blowing agents, play the most important role in ozone depletion. Though scientific debate on ozone depletion has occurred for over a decade, only in 1987 was an international landmark protocol signed in Montreal to reduce the production of CFCs and halons. Conclusive scientific evidence of the destruction of stratospheric ozone by CFCs and halons has recently been gathered, and commitments for more drastic reductions in their production were undertaken at the 1990 London Conference [8]. Replacement products and technologies without CFCs are gradually coming to the fore and should help allow for a total ban of CFCs ultimately. An important consideration in such a CFC ban is the need to distribute fairly the economic burdens deriving from the ban, particularly with respect to developing countries, some of which have invested heavily in CFC-related technologies.

2.3. Greenhouse effect (global climate change)

Potentially the most important environmental problem relating to energy utilization is global climate change, also known as the global warming or the greenhouse effect. Increasing concentrations of greenhouse gases such as CO_2, CH_4, CFCs, halons, N_2O, ozone and peroxyacetylnitrate in the atmosphere are increasing the manner in which these gases trap heat radiated from the earth's surface, thereby raising the surface temperature of the earth. The earth's surface temperature has increased about 0.6°C over the last century, and, as a consequence, the sea level is estimated to have risen by perhaps 20 cm [9]. Such changes can have wide-ranging effects on human activities all over the world. Currently it is estimated that CO_2 contributes about 50% to the anthropogenic greenhouse effect. In Table 1, current

Table 1
Role of different substances in the greenhouse effect[d]

Substance	ARIRR[a]	Atmospheric concentration		Annual growth rate (%)	SGEHA[b] %	SGEIHA[c] %
		Pre-industrial (ppm)	Present (ppm)			
CO_2	1	275	346	0.4	71	50 ± 5
CH_4	25	0.75	1.65	1	8	15 ± 5
N_2O	250	0.25	0.35	0.2	18	9 ± 2
R-11	17 500	0	0.00023	5	1	13 ± 3
R-12	20 000	0	0.00040	5	2	13 ± 3

[a] Ability to retain infrared radiation relative to CO_2.
[b] Share in the greenhouse effect due to human activities (%).
[c] Share in the greenhouse effect increase due to human activities (%).
[d] Source: Aebischer et al. [10].

knowledge of the role of various greenhouse gases is summarized. Humankind is contributing through many of its economic and other activities to the increase in the atmospheric concentrations of various greenhouse gases. For example, CO_2 releases from fossil fuel combustion, methane emissions from increased human activity, CFCs releases and deforestation all contribute to the greenhouse effect.

Energy-related activities contribute both directly and indirectly to the generation of CO_2 and other potent greenhouse gases. CO_2 emissions from fossil-fuel combustion are estimated to account for half of the radiative balance changes caused by greenhouse gases. Methane emissions, which partly arise from natural gas leaks and coal mines, account for a significant fraction as well. The U.S. Environmental Protection Agency (EPA) study, aimed at determining policy options for stabilizing climate change, concluded that, in a rapidly changing world, it is possible to restrain emissions of greenhouse gases considerably through efforts aimed specifically at changing patterns of energy production and use (e.g. the implementation of energy conservation measures, increased use of biomass and some fuel switching). With the adoption of such measures, the increase in realized warming — an important indicator of global climate change — could be restrained to only 2°C between 2000 and 2100 as compared to 5°C in the most extreme case. The report emphasized, however, that if industrialized countries were to embark on a climate stabilizing strategy without the involvement of developing countries, global temperatures would rise by 3.6°C by 2100 [11]. Hence, crucial to the success of future emissions abatement efforts will be the participation of all countries-both industrialized and developing.

In recognition of this need for global participation in activities to stem the growth in greenhouse gas emissions, the EPA supported two sets of studies aimed at investigating future emissions levels and potential emissions reduction policies in a range of countries. The International Energy Studies Group at the Lawrence Berkeley Laboratory initiated a study to examine the long-term contribution of energy sources to carbon emissions from developing countries: the study was conducted in collaboration with local experts at research institutions in 11 developing nations and resulted in the development of case studies for Brazil, India, China, Indonesia, South Korea, Mexico, Ghana, Sierra Leone, Nigeria, Argentina, Venezuela and the six member countries of the Gulf Cooperation Council (GCC) (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates). The study countries include some of the developing world's largest consumers of energy, including biomass [12]. The country studies provide evidence to support the EPA's emphasis on the growing contribution of developing countries to global emissions of greenhouse gases. Estimates of future data culled from the scenarios suggest that developing countries are the fastest growing source of CO_2 emissions and will be the largest source of total emissions within the next 20 years. According to the scenarios, emissions of CO_2 from 17 major developing countries will reach 3.6 billion tonnes in 2025 compared to 0.9 billion tonnes in 1985. The magnitude of the increase is equivalent to adding twice the amount of carbon emissions generated by the USA today to the present developing world total. The long-term scenarios indicate that CO_2 emissions from the 17 developing countries can be reduced to 2.8 billion tonnes through efficiency improvements and fuel-switching measures. China's predominant contribution to total emissions was highlighted in the report. Emissions of CO_2 from China amount to 480 million tonnes or almost 53% of the total emissions in the studies countries in 1985. This figure will increase to 1.7 billion tonnes in 2025 despite a continued reduction in energy intensity (energy use per unit of GDP). The China report suggests that the nation's emissions can be reduced by 21%, but achieving this reduction is predicated upon adopting measures and policies which would entail considerable costs. In each of the study countries, restraining the growth of energy use, and consequent emissions, would require that the energy intensity of the economy declines or increases less between now and 2025 and/or that each country shift to the use of less carbon-intensive fuels.

The studies indicated that the greatest opportunity for reducing emissions in the studied countries lies in improving energy efficiency. Given the limited alternative resources of oil and gas everywhere, except in the GCC countries, Venezuela and Russia, the potential for switching among domestic fuels is limited and, due to the scarcity of hard currency, the prospect of importing these fuels appears bleak. Achieving the potential gains associated with improved energy efficiency will entail a concerted effort on the part of consumers, manufacturers, energy-supply companies and governments. The results of the country studies provide a range of options for surmounting the potential obstacles to energy efficiency improvements. Mechanisms are needed which would provide incentives for these groups to work together towards the common goal of more efficient energy production and use. Requiring large industries to prepare an energy efficiency-impact statement and providing incentives in the form of tax breaks is one approach to improving the efficiency of new products. Incentives for the accelerated replacement and decommissioning of existing equipment are important to reduce the energy currently wasted in carrying out many end-use activities.

While improving energy efficiency will slow the growth of energy use and carbon emissions, it will not reverse the trend towards increased energy use required to support economic growth. Dramatically decreasing the energy requirements of economic development would require fundamental changes in the way societies develop. Increased use of power and motive force, higher comfort levels and the desire for greater convenience is the current paradigm in industrialized countries which normally leads to an increase in carbon emissions. The emulation of this paradigm has already led to urban blight in most developing countries.

Consequently, it is important to point out that a significant characteristic of each of the examples of regional and global pollution problems mentioned above is that the nature and magnitudes of the damages caused are subject to major uncertainties. For example, in the acid rain, uncertainties relate mainly to the magnitudes of the physical and biological effects, rather than to be nature of the effects themselves, and to the transformation of these physical and biological impacts into economic damages. For ozone depletion, uncertainties are far more comprehensive because the phenomenon of ozone depletion is not well understood and research conducted on ozone depletion is based mostly on model-oriented studies. In addition, there are various uncertainties in terms of the processes and consequences of global climate change, such as the regional impacts of the various manifestations of the process and the timing of the changes and their consequences.

3. Some potential solutions to current environmental issues

Recently, some potential solutions have evolved regarding the possible problems associated with CO_2 emissions, including: energy conservation through improved energy efficiency, a reduction in the usage of fossil fuels and an increase in the supply of environmentally benign energy forms, which is leading to the use of renewable energy sources and technologies, acceleration of forestation to absorb CO_2, and reduced energy usage by changing life styles and increasing public awareness.

It is important to mention that there are some possibilities to substitute fossil fuels (i.e., coal and oil) by alternative fuels or fuels with less carbon content. For example, in the case of the iron and steel industry, it is difficult to operate blast furnaces with oil or gas, but energy-intensive industries, such as the cement and paper industries use less coal and more gas. The mechanical and the assembly industries can utilize mainly gas, which is easy to handle and control. However, it is necessary to accelerate this substitution by appropriate subsidies to overcome price barriers, which are the major obstacles for many industrial applications.

Below we discuss two of the most important options, namely energy conservation and use of renewable energy technologies.

3.1. Energy conservation and energy efficiency

A number of factors are considered to be important in determining the future level of a country's energy consumption and production, including population growth, economic performance, consumer tastes, technological developments, government policies concerning the energy sector, and developments on world energy markets.

Energy resources and their utilization are intimately related to sustainable development. For societies to attain or try to attain sustainable development, much effort must be devoted not only to discovering sustainable energy resources, but also to increasing the energy efficiencies of processes utilizing these resources. Under these circumstances, increasing the efficiency of energy-utilizing devices is important. Due to increased awareness of the benefits of efficiency improvements, many institutes and agencies have started working along these lines. Many energy conservation and efficiency improvement programmes have been and are being developed to reduce present levels of energy consumption. To implement these programmes in a beneficial manner, an understanding is required of the patterns of "energy carrier" consumption, for example, the type of energy carrier used, factors that influence consumption, and types of end-uses [13].

Energy conservation involves efficiency improvements, formulation of pricing policies, good "housekeeping practices," and load management strategies, among other measures. A significant reduction in consumer energy costs can occur if conservation measures are adopted appropriately. The payback period for many conservation programmes is less than two years. In recent years, an energy conservation programme has been introduced [14] for the electrical sector in India that is considered both technically feasible and economically promising. In spite of the potentially significant benefits of such programmes to the economy and their proven successes in several countries, conservation programmes have not yet been undertaken on a significant scale in many developed and developing countries. Some reasons for this lack of conservation programmes relate to the following factors:

- technical (e.g. lack of availability, reliability, and knowledge of efficient technologies),
- institutional (e.g., lack of appropriate technical input, financial support, and proper programme design and monitoring expertise),
- financial (e.g., lack of explicit financing mechanisms),
- managerial (e.g., inappropriate programme management practices and staff training),
- pricing policy (e.g., inappropriate pricing of electricity and other energy commodities), and
- information diffusion (e.g., lack of appropriate information).

Reduced energy consumption (through conservation) programmes can benefit not only consumers and utilities, but society as well. In particular, reduced energy consumption generally leads to reduced emissions of greenhouse gases and other pollutants into the environment.

Energy conservation is vital for sustainable development and should be implemented by all possible means, despite the fact that it has its own limitations. This is not only required for us but for the next generation as well. Energy conservation is of great importance in terms of sectoral energy utilization and Table 2 is an example to show the potential energy savings in British industry which used 2410 PJ of energy in 1986. As can be seen from the table, the scope for industrial energy savings is between 24 and 34% of the total industrial fuel used. Of course, this is only a generalization. Some industries, particularly, those where appreciable quantities of high grade waste heat are produced, lend themselves to waste-energy recovery far better than others, which need mainly mechanical and electrical energy. Furthermore, there is no doubt that some factories are already run along extremely energy economical lines, while others are negligent in this respect.

Table 2
Potential scope for energy savings in British industry[a]

Type of energy saving	Amount (PJ)
Waste heat recovery	216–288
Waste as fuel	108–180
Improved instrumentation and control	72–108
Heat pumps	36
Process insulation	36
Improved drying and evaporation practice	36
Industrial combined heat and power plants	36
Improved methods of driving machinery	72–108
Total savings	612–828

[a] Source. [2].

Furthermore, some technical limitations on energy conservation are associated with the laws of physics and thermodynamics. Other technical limitations are imposed by practical technical constraints related to the real-world devices that are used. For example, the minimum amount of fuel theoretically needed to produce a specified quantity of electricity could be determined by considering a Carnot (ideal) heat-engine. However, more than this theoretical minimum fuel may be needed due to practical technical matters such as the maximum temperatures and pressures that structures and materials in the power plant can withstand

As environmental concerns such as pollution, ozone depletion and global-climate change became major issues in the 1980s, interest developed in the link between energy utilization and the environment. Since then, there has been increasing attention to this linkage. Many scientists and engineers suggest that the impact of energy-resource utilization on the environment is best addressed by considering exergy. The exergy of a quantity of energy or a substance is a measure of the usefulness or quality of the energy or substance, or a measure of its potential to cause change. Exergy appears to be an effective measure of the potential of a substance to impact the environment. In practice, the author feels that a thorough understanding of exergy and how exergy analysis can provide insights into the efficiency and performance of energy systems are required for the engineer or scientist working in the area of energy systems and the environment. Although many studies exist concerning the close relationship between energy and the environment, there have been limited works on the link between exergy and environment concepts [19–21]. In addition, exergy analysis has recently been proposed by many scientists and engineers as a technique for thermodynamic assessment that overcomes most, if not all, of the problems associated with energy analysis [15,16].

3.2. Renewable energy technologies

The operating and financial attributes of renewable energy technologies, which include modularity and flexibility, low operating costs (suggesting relative cost certainty), are considerably different from those for traditional, fossil based technologies, whose attributes include large capital investments, long implementation lead times, and operating cost uncertainties, regarding future fuel costs. The overall benefits of renewable energy technologies are often not well understood and consequently they are often evaluated to be not as cost effective as traditional technologies. In order to assess comprehensively renewable technologies, however, some of their benefits that are often not considered must be accounted for. Renewable energy technologies, in general, are sometimes seen as direct substitutes for existing technologies so that their benefits and costs are conceived in terms of assessment methods developed for the existing technology. For example, solar and other renewable energy technologies can provide small incremental capacity additions to existing energy systems with short lead times. Such power generation units usually provide more flexibility in incremental supply than large, long lead-time units such as nuclear power stations.

The development of renewable energy other than hydro-electric power has in part been limited by the focus of electric utilities on fossil and nuclear energy options. Non-fossil energy farms will nevertheless likely have a role in abating greenhouse gas emissions, although the scale of this contribution will likely be limited in the short term.

4. Energy and sustainable development

A secure supply of energy resources is generally agreed to be a necessary but not sufficient requirement for development within a society. Furthermore, sustainable development demands a sustainable supply of energy resources. The implications of these statements are numerous, and depend on how sustainable is defined.

One important implication of these statements is that sustainable development within a society requires a supply of energy resources that, in the long term, is readily and sustainably available at reasonable cost and can be utilized for all required tasks without causing negative societal impacts. Supplies of such energy resources as fossil fuels (coal, oil, and natural gas) and uranium are generally acknowledged to be finite; other energy sources such as sunlight, wind and falling water are generally considered renewable and therefore sustainable over the relatively long term. Wastes (convertible to useful energy forms through, for example, waste-to-energy incineration facilities) and biomass fuels are also usually viewed as sustainable energy sources.

A second implication of the initial statements in this section is that sustainable development requires that energy resources be used as efficiently as possible [4,5]. In this way, society maximizes the benefits it derives from utilizing its energy resources, while minimizing the negative impacts (such as environmental damage) associated with their use. This implication acknowledges that all energy resources are to some degree finite, so that greater efficiency in utilization allows such resources to contribute to development over a longer period of time, i.e., to make development more sustainable. Even for energy sources that may eventually become inexpensive and widely available, increases in energy efficiency will remain sought after to reduce the resource requirements (energy, material, etc.) to create and maintain systems and devices to harvest the energy, and to reduce the associated environmental impacts.

The first implication, clearly being essential to sustainable development, has been and continues to be widely discussed. The second implication, which relates to the importance and role of energy efficiency in achieving sustainable development, is less discussed and understood.

5. Environment and sustainable development

Environmental concerns are an important factor in sustainable development. For a variety of reasons, activities which continually degrade the environment are not sustainable over time, e.g., the cumulative impact on the environment of such activities often leads over time to a variety of health, ecological and other problems.

A large portion of the environmental impact in a society is associated with its utilization of energy resources. Ideally, a society seeking sustainable development utilizes only energy resources which cause no environmental impact (e.g., which release no emissions to the environment). However, since all energy resources lead to some environmental impact, it is reasonable to suggest that some (not all) of the concerns regarding the limitations imposed on sustainable development by environmental emissions and their negative impacts can be in part overcome through increased energy efficiency. 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.

Improved energy efficiency leads to reduced energy losses. Most efficiency improvements produce direct environmental benefits in two ways. First, energy input requirements are reduced per unit output, and pollutants generated are correspondingly reduced. Second, consideration of the entire life cycle for energy resources and technologies suggests that improved efficiency reduces environmental impact during most stages of the life cycle.

6. Illustrative example

The contribution to sustainable development in a society, possible through the provision of heat and electricity services through cogeneration rather than through separate processes for heat production and electricity generation, is considered, based on the results of a previous study [17]. The key points demonstrated are that, for the several scenarios considered, energy use and environmental emissions decrease in a society through cogeneration, e.g., annual electricity consumption decreases by as much as 30%, permitting annual electrical generation to decrease correspondingly; annual fuel use and related emissions for the electrical utility sector both decrease by up to 47%; and, excluding the electrical utility sector, the society's annual use of fossil fuels and the corresponding annual emissions both decrease by up to 15%. It is noted that this is but one limited illustration of how increased energy efficiency can contribute to sustainable development. Numerous other areas in which increased energy efficiency can contribute exist in any society.

7. Conclusions

Energy resources and their utilization are intimately related to sustainable development. For societies to attain or try to attain sustainable development, much effort must be devoted not only to discovering sustainable energy resources, but also to increasing the energy efficiencies of processes utilizing these resources. Further, environmental concerns must be addressed. Several important observations can be drawn from the present study as follows:

- Action will be required on a considerable scale if stabilization or reduction of greenhouse gas emissions is to be achieved.
- There exist numerous scientific uncertainties regarding many of the details associated with the global-warming problem. Much debate is occurring

regarding the predicted qualitative and quantitative impacts of global warming, and the timing for the effects.

- Although energy industries will be significantly impacted by shifts towards sustainable development, they have in the past demonstrated a capacity to respond if prompted by government actions and other factors.
- Although the mix of non-fossil, nuclear and renewable energy sources may vary as efforts are made to promote sustainability, a main contribution is going to come from increased energy efficiency.
- Market-based regulatory instruments, such as carbon or fuel taxes, will remain a vital component of policies to reduce emissions of carbon dioxide and other pollutants, since efforts to increase energy efficiency and reduce environmental impact are usually unsupportable against a background of low prices.
- In sectors where consumers do not purchase devices with improved efficiency and environment characteristics, market signals will certainly have to be supplemented by more direct government intervention (e.g., transport and domestic appliances are often purchased with little attention to efficiency and environmental impact).

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