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Energy, Environment and Sustainability: The Challenge of Carbon Dioxide Emissions

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Abstract—**Anthropogenic activities are altering the composition of the atmosphere and contributing to climate change. With such predominance, inquiries on how to protect the environment are of high importance. Uncompromising examinations based on both scientific and ethical frameworks can play a defining response towards such inquiries. An ethical proposition is a distinctive, authoritative, and often overlooked overture to impact transform in environmental management strategies. Though scientific analysis can determine the consequences of environmental action, ethics can establish guiding principles that can govern such action. The ethical framework is appraised with respect to some of the problematic issues of sustainable energy development. As human demand for energy resources increases, the viability and sustainability of energy resources and their efficient and effective use are becoming critical public issues. However, the diverse environmental and social ramifications of energy use do make assessing its sustainability difficult. Nonetheless, indexes of sustainable energy development (SED) can be clear markers of progress towards sustainability. Examining indexes of SED is also advantageous because they are still in the development stage; critiques can still readily influence their structure. Furthermore, Monitoring CO_2 emissions from energy use is considered as one of the best single indicators of the sustainability of energy use. CO_2 emissions account for over half of the anthropogenic greenhouse effect; because the vast majority of CO_2 emissions result from energy use, mostly from fossil fuel use; and because fossil fuels comprise around eight-five percent of the world's marketed energy supply. This study will focus on investigating the issue of energy sustainability through carbon dioxide emissions index.**

Keywords-energy resources, sustainability, environmental ethics, emissions and management.

I. ENERGY

A. Fossil Fuels

A short list of the negative consequences of fossil fuel use includes air, water and land pollution from mining, drilling, spilling oil, and transporting fossil fuels; conflicts over fuel resources; and the many effects of burning fossil fuels including smog, acid rain, and global warming. Of course, fossil fuels have significant advantages compared to traditional biomass fuels. Additionally, the energy density, the amount of energy that can be released from a unit of mass, of fossil fuels is significantly greater than that of traditional biomass sources [1]. Thus, to obtain the same amount of energy far fewer pounds of fossil fuels than of biomass fuels need to be burned. The high energy densities of fossil fuels also enable them to be efficiently transported over long distances because they take up less room in trains or barges. Consequently, population centers do not need to be located at the fuel source. The comparatively small land requirements and large transportation efficiencies of fossil fuels also enabled industry to develop on a larger scale than was ever possible with traditional biomass fuels - more energy could be concentrated at one place with fossil fuels. Finally, because fossil fuels are such concentrated energy sources, they can be efficient fuels for vehicles. These advantages have not gone unnoticed; in 2000, fossil fuels accounted for eighty-five percent of the marketed energy used worldwide [2].

B. Climate Change

The Intergovernmental Panel on Climate Change (IPCC) has concluded that anthropogenic emissions of long-lived greenhouse gases (GHGs) are responsible for an enhanced greenhouse effect that is raising the planet's average surface temperature and accelerating rates of climate change [3]. The primary GHGs – carbon dioxide (CO_2), methane (CH4), and nitrous oxide (N2O) – differ in their global warming potential due to distinct radiative properties and atmospheric residence times. Consequently, GHG emissions and atmospheric concentrations are expressed in terms of CO_2 -equivalents (CO_2e), which is the amount of CO_2 that would be needed to cause the same radiative forcing over a given time period [3]. Global consumption of fossil fuels is expected to increase 57% from 390 to 610 EJ, which will cause a 58% rise in energy-related emissions from 26.6 to 41.9 Gt CO_2e over 2005-2030 (see Fig.1.) [4]. The concentration of CO_2 in the atmosphere rose from a pre-industrial level of 280 to 379 ppmv (parts per million by volume) by 2005 [4]. Climate models predict that global warming could be limited to 2.0 to 2.4°C above pre-industrial levels by stabilizing atmospheric CO_2e concentration at 450 ppmv [4]. A larger average rise in global surface temperatures is almost certain to cause significant disruptions such as flooding of densely populated coastal areas, more extreme weather events, and higher risks of disease and water shortages [5, 4]. Global energy-related GHG emissions would then have to peak and decline to 23 Gt CO_2e by 2030 (Fig. 1.) and drop to 50% to 85% below 2000 levels by 2050 (12 to 3.5 GtCO_2e) [4]. The business as usual projection is consistent with stabilization at 855-1130 ppmv, which could warm the planet 6.1°C above pre-industrial levels and lead to unpredictable consequences.

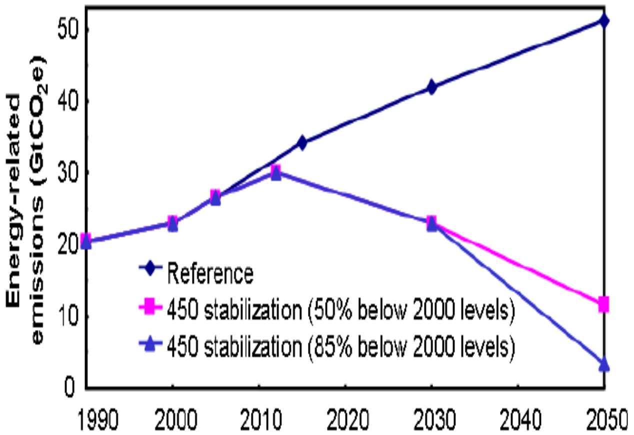

Fig. 1. Global energy-related GHG emissions over 1990-2005 and projections to 2050 [4].

In the past 25 years energy-related emissions grew more slowly than primary energy demand as the use of nuclear power and natural gas expanded [4]. The rise in the use of coal in developing countries is projected to reverse this trend and recarbonize global fuel supplies even though decarbonization is needed to mitigate GHG emissions [6]. The IPCC estimates that world GHG emissions need to be reduced 50% to 85% below 2000 levels by 2050 to stabilize atmospheric CO2e concentration at 450 ppmv [4]. Based on equity principles, industrialized countries must reduce their emissions by a greater amount (80% below 1990 levels by 2050) [5]. However, The world is not headed towards a sustainable energy future. Growing consumption of oil and natural gas threatens the world's energy stability while the resurgence of coal is raising the carbon intensity of the global economy. Alternative approaches that mitigate energy security and climate change risks are highly needed.

C. *Energy Outlook*

Secondary fuels such as electricity and gasoline are derived from three categories of primary energy – fossil fuels, nuclear, and renewable energy [7]. Population and economic growth drive a society's primary and secondary energy demand. The International Energy Agency's [4]. World Energy Outlook predicts that population will grow 32% from 6.2 to 8.2 billion people over 2005-2030. Most of this growth is expected to occur in the fast-growing economies of the developing world. The most populated countries (China and India) are expected to experience the most economic growth over 2005-2030. Industrialization generally requires huge inputs of energy to build infrastructure and upgrade the standard of living [8]. The industrialization of developing countries is largely responsible for the anticipated 55% increase in primary energy demand from 480 to 740 EJ over 2005-2030 [4], which will intensify competition for global energy resources. The corresponding increase in primary energy supplies is expected to require an investment of $22 trillion in energy-supply infrastructure (IEA, 2007). Fossil fuels such as oil, coal, and natural gas supply most of the world's energy. The global energy supply mix in 2005 was 81% fossil fuels while the rest was biomass and waste, nuclear, hydro, and other renewables (Table 1.). Consumption of all energy sources is expected to increase over the period to 2030, especially coal for power generation. The Energy Information Administration's [9]. International Energy Outlook indicates that the US, China, and India have large domestic deposits and are expected to turn to coal-fired power in lieu of more expensive fuels. Global coal production is expected to increase 73% from 4,154 to 7,173 Mt over 2005-2030 to supply power to developing economies [4]. The petroleum industry produces the majority of the world's transportation fuels and chemical products. Crude oil production is expected to increase 37% from 84.6 to 116.3 million barrels per day (Mbpd) over 2006-2030 to meet growing demand in developing countries [4]. Global reserves are increasingly concentrated in a small group of countries; for example, the Organization of Petroleum Exporting Countries' (OPEC) market share of oil supply is predicted to jump from 42% to 52% over 2006-2030 [4]. The real (inflation-adjusted) price of petroleum has steadily increased since 1997 as supplies have stretched to meet demand (Fig. 2.).

II. THE QUESTION OF SUSTAINABILITY

The *Brundtland Report* [10] and Agenda 21 from the United Nations Conference on Environment and Development (UNCED Earth Summit), in Rio de Janeiro, 1992 [11]., popularized and lent international legitimacy to the concept of sustainable development. The *Brundtland Report* defined sustainable development as human development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs" [10]. Agenda 21 recognized humanity's dependence on the natural environment and thus the necessity to protect it for current and future generations [11].

Table 1. Global energy supply mix 1980-2030 according to the reference scenario of World Energy Outlook 2007 [4].

Primary energy source	**Fraction of supply mix** 1980	2005	2030	**Growth rate (2005-2030)**
Oil	43%	35%	32%	1.3%
Coal	25%	25%	28%	2.2%
Natural gas	17%	21%	22%	2.1%
Biomass and waste	10%	10%	9.1%	0.7%
Nuclear	2.6%	6.3%	4.8%	2.0%
Hydro	2.0%	2.3%	2.3%	1.4%
Other renewables	0.2%	0.5%	1.7%	6.7%
Total	100%	100%	100%	--

Agenda 21, followed by various other international conventions and agreements, strengthened the commitment to sustainable development and recognized that natural resources must be managed for the benefit of future generations. Intergenerational equity is important for the shift from short-term thinking to long-term planning. Sustainability extends moral consideration to the future. Mitchell and Shrubsole suggest that sustainable development embodies the following aspects: meeting basic needs; maintaining ecological integrity and diversity; merging environment and economics in decision making; keeping options open for future generations; reducing injustice; and increasing self determination [12]. Since using energy is necessary for all human activity and has many serious side effects for humanity and for the environment at large, focusing on energy use is one of the most effective ways to monitor movement toward sustainability. The diverse environmental and social ramifications of energy use do make assessing its sustainability difficult; yet, indexes of sustainable energy development (SED) aim to do just that. In particular, SED indexes monitor movement toward or away from SED, which can be broadly defined as "the provision of adequate energy services at affordable cost in a secure and environmentally benign manner, in conformity with social and economic development needs." [13]. Indexes are not the only means of assessing the sustainability of energy use. Qualitative assessments of SED and quantitative data too complex to be included in the indexes are also important. This chapter will focus on indexes to keep it manageable, and emphasize that ethics influences even these quantitative measures. Examining indexes of SED is also advantageous because they are still in the development stage; critiques can still readily influence their structure. While assessments of SED indexes have focused on their technical merits, index developers recognize that technical critiques are not sufficient to account for the normative dimension of sustainability.

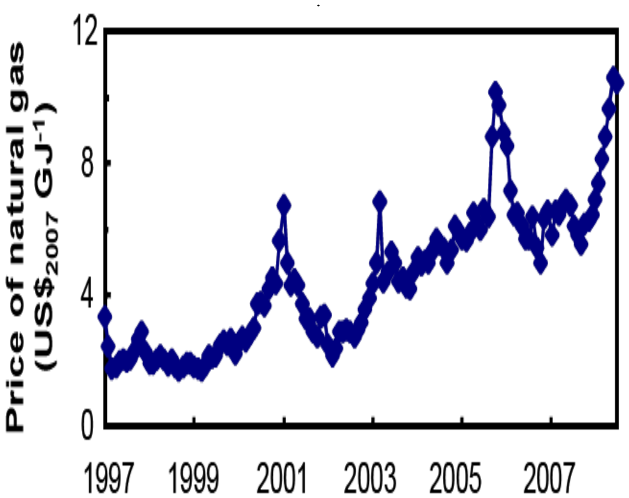

Fig. 2. Real wellhead price of North American natural gas from January 1997 to July 2008 [9]

Definitely, they recognize the need to consider diverse ethical perspectives to ensure that the indexes are ethically sound before they are adopted. In order to fill this gap in the literature, this study will focus on carbon dioxide emissions.

A. Relaibility

Reliability implies the adequate, honest, accurate, assessment of the situation in which an ethical decision or action is to be made. The situation can consist of several elements: the world, as it exists apart from humanity, the world in relation to humanity and the actions and capabilities of humanity as a whole and as individuals. It also reflect virtues like humility and pride that together promote the balance between realizing one's limits and using one's strengths [14]. The adequate assessment of the situation also evaluates who can best address an issue and the level of cooperation needed to do so. Consequently, it encourages attentiveness to scientific knowledge about ecosystems, industrial processes, pollution, and human needs; sociological, psychological, and religious knowledge about the imperfections of people that necessitate laws, punishment, and forgiveness; and ethical knowledge of the virtues needed to adhere as closely as possible to our ideals as specified in this and other principles. Moreover, adequate assessment of the situation necessarily relies upon metaphysical and ontological assumptions about the world, for example, whether it has intrinsic value. However, this principle encourages people to consider all of the sorts of data and methods they find relevant and discover what this information indicates about the situation at hand. Over time, these data and methods can be assessed for adequacy based on how well they mesh with experience and prevent environmental degradation.

B. Adaptability

Adaptability encourages adaptation of people and policies to the world and the knowledge of it, both of which continually change [15]. Adaptability includes incorporating precaution into developed policies given the inherent limits of knowledge of the world and uncertainties about its changing conditions [14]. Adaptability also can imply sensitivity to the particular cultural and environmental contexts. This principle is separated from adequate assessment of the situation due to the dynamic nature of the world to avoid clinging to one approach or one segment of knowledge.

C. Carbon Emissions

Monitoring CO_2 emissions from energy use is considered as one of the best single indicators of the sustainability of energy use. CO_2 emissions account for over half of the anthropogenic greenhouse effect; because the vast majority ofCO2 emissions result from energy use, mostly from fossil fuel use; and because fossil fuels comprise around eight-five percent of the world's marketed energy supply. After recent efforts to raise awareness about climate change, it may seem surprising that SED indexes focus on CO_2 *emissions* since all of these documents emphasize that *concentrations* of CO_2 in the atmosphere are higher now than they have been in the past 600,000 years [13]. While both emission and concentrations data can be helpful for environmental decision-making, CO_2 emissions are particularly appropriate measures of the sustainability of energy use. Emissions data measures the amount of a product, in this case CO_2, emitted by a process, company, or nation. Generally, records of carbon emissions focus on the emissions from human activities. If tracked over time, anthropogenic emissions data indicate whether humans are contributing more or less CO_2 to the atmosphere than previously contributed. Concentration measurements refer to the number of molecules of a particular gas per million or billion molecules in the atmosphere. Carbon dioxide concentrations are reported in parts per million (ppm). Information about atmospheric concentrations of CO_2 is useful because it correlates with the environmental impact of CO_2 in the atmosphere. Certainly, emissions and concentrations data are related since higher emissions enables more gas to end up in the atmosphere.

However, the two variables are not necessarily directly proportional. Carbon dioxide emitted by humans may be taken in by plants before it raises atmospheric concentrations. Additionally, a molecule of CO_2 has an average atmospheric lifespan of around a century so concentrations will remain high long after emissions decrease. It is true that atmospheric concentrations of CO_2 may better predict climate change than emissions levels because emitted CO_2 can be absorbed before it reaches the atmosphere. However, the global nature of the atmosphere means that the concentrations of CO_2 emissions from anyone nation's activities must be calculated based on their emissions data and the absorption rates of CO_2. Assuming that C02 absorption is roughly constant, CO_2 emissions will correlate with a country's present contribution to global warming. Thus, monitoring emissions is essential for tracking a country's climactic impact due to its current energy use.

D. *Measures*

Several measures of CO_2 emissions can serve as an indicator for SED, each of which focuses on a different aspect of sustainability. The basic method records the amount of CO_2 emitted, a measure that roughly indicates the total environmental impact of this greenhouse gas [16]. Alternatively, the CO_2 emitted per capita or per GDP will indicate the value obtained from each unit of emissions [2]. Monitoring CO_2 emissions per capita also facilitates comparisons between countries since it takes account of population differences. Tracking the energy per capita or per GDP as well as total emissions can help determine whether changes in emission levels are linked to major social or economic changes (industrialization, war or economic depression) or if they are due to changes in the structure of energy use itself (less manufacturing and more services). While such knowledge is important for evaluating current and potential policies, focusing on the CO_2 emitted per capita or per unit of GDP can divert attention from the environmental impact of emissions. After all, these measures mask the fact that the total environmental impact of emissions will increase if the population rises more quickly than the CO_2 emitted per capita decreases. However, the amount of emissions can be the best indicator because emissions influence the environment. In turn, the state of the environment affects society and the economy. This sequence is not captured by measures of the CO_2 emitted per capita or per GDP, yet it is essential to SED.

Emissions indicators will be most influential in policy-making if they can reveal both the activities that most significantly contribute to emissions as well as the types of energy sources that produce the most emissions given the structure of energy used in a nation. When this information is known, policies can target the most destructive activities.

Generating this consolidated information while remaining relatively incomlex, emissions indexes need to be capable of classification. In other words, the index's single output value needs to be easily separable into its constituent parts whether sectors of the economy or types of energy used.

In the United States, the Energy Information Administration (EIA) monitors the CO_2 emitted by the country as a whole and by the four sectors of the economy: residential, commercial, industrial, and transportation. Emissions of each sector are tracked by estimating the direct fuels such as coal and natural gas used by the sector, the electricity purchased by the sector, and the industrial processes attributable to particular sectors [17]. In such manner, policy-makers can track the sectors that contribute most to climate change and assess whether policies to reduce emission are working. The EIA can divide the data by focusing on the emissions produced per fuel, or by the activities that make up particular sectors. For example, transportation emissions are easily broken down by fuel type (motor gasoline, diesel fuel, jet fuel, and residual oil). Industrial emissions can be analyzed by industry (manufacturing, "agriculture, forestry, fishing, mining, and construction…) [17]. This classification allows analysts to identify the activities that contribute most to climate change and thus the areas where efficiency measures or restrictive laws may make the most difference. For example, the transportation sector produces more CO_2 emissions than any other sector in the United States and sixty percent of its emissions come from gasoline. In fact, burning gasoline emits more CO_2 than the entire commercial sector and almost as much as the residential sector [17]. Thus, reducing CO_2 emissions from gasoline use would have a substantial impact on overall CO_2 emission in the United States.

While most emissions data focuses on gross emissions, some analysts try to monitor net emissions. They write off actions to offset CO_2 emissions such as planting trees from a nation's total CO_2 emissions. A move to monitoring net emissions would improve the correspondence between the index results and the actual rates of climate change but would add an extra degree of complexity to the index especially since estimating CO_2 uptake for large tracts of vegetation is a difficult process. To avoid this complexity and produce more certain data, mitigation efforts are not usually included in emissions data. Though reliable mitigation data was available, a pure emissions index have a variety of advantages as a proxy index for SED. In addition to being easy to calculate and use, it would focus on the most significant consequences of energy use given the fossil fuel dominated energy mix in use today. Taking the degree to which the CO_2 emissions index focuses on the several aspects of energy use that will have the largest effect on the environment, human society, and the economy for centuries it is a quite farsighted index. However, it is often easier to focus on effects of actions that are both exceedingly visible and affect local environments. Water pollution in a nearby region or toxic waste near an establishment typically inspires action more than environmental damage thousands of miles away or years in the future. The index can help people overcome their local biases to examine the problems most significant in time and space.

While the CO_2 index's narrow focuses on gross CO_2 emissions has many advantages, its narrow focus can be a liability if it is taken to be the only important or necessary way of assessing the world. Particularly, focusing on CO_2 emissions as the index of SED raises the question of whether it is better to focus solely on the largest problem of energy use, or use a more comprehensive approach. Can a simplified measure of the complex interactions between humans and the larger environment such as the CO_2 emissions index have an impact on the sustainability of a country's energy use?

Certainly, this question has an empirical answer but irrevocable damage to the environment could occur before such an answer can be found. Thus, a narrow focus on CO_2 emissions today may play a distractible role in avoiding behaviors that will become major problems in the future. If CO_2 emissions are to be *the* indicator of SED, a simplistic picture and that the strategy of monitoring SED may need to be adjusted as other environmental problems grow.

III. CONCLUSIONS

Since the CO_2 emissions index cannot register the distributional disparity of benefits and harms of CO_2 emissions, it only follows the principle of justice in the most elementary way: decreasing CO_2 emissions is an environmental achievement. While the CO_2 index is limited in its scope, as are all narrowly focused indicators of complex systems, a sight of advantages of this index must not be lost: Its relative simplicity allows it to be more easily understood than complex, multidimensional indexes that track many ramifications of energy use. Moreover, its focus on CO_2 emissions enables it to monitor the largest contributor to climate change, the most significant problem of energy use facing the world today. If a more complex understanding of movement toward SED is desired, a more intricate index will be required.

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