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"Beyond Supply and Scarcity: An Examination of Energy Systems, Externalities, and the Move Toward Renewable Resources"

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A Thesis

in

The Department

of

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Abstract

"Beyond Supply and Scarcity: An Examination of Energy Systems, Externalities, and the Move Toward Renewable Resources"

Dwayne G. Pretli

One of the most important issues concerning social development and technological progress is, and always has been, that of energy use. Any salient study that begins from this premise must inevitably attempt an incredibly complex and multi-dimensional analysis. Unfortunately, all too often, the methodologies employed to examine issues embedded within contemporary human energy systems become limited to restrictive and one-dimensional studies. Consequently, an in-depth understanding of even the basic aspects and implications of energy use is often lost. No better example of this exists than that which is found within the present-day dependence on fossil fuels and, subsequently, attempts to address the myriad of social, political, economic, and ecological problems that stem directly from the burning of these fuels. A limited or restricted understanding of energy use not only camouflages these many diverse (but interrelated) problems, it also serves to prohibit an awareness and acceptance of alternative solutions - most visibly, it limits the modern debate regarding the feasibility of renewable energy sources.

This thesis begins with an examination of the various multifaceted issues facing human energy use, illustrating the contention that the theoretical framework upon which modern energy studies are built must be expanded. Accordingly, it is maintained that a comprehensive study of modern energy systems and, similarly,

modern energy use. which employs more than the standard one-dimensional analysis technique. will help to explore many currently overlooked problems. as well as the interconnected foundations of these same problems. Consequently. it is argued that any attempt to develop policies pertaining to the notion of social development, when maintaining a focus on energy use, must begin from this starting point. The primary goals of this thesis are. therefore. to simply: (1) depict the manner in which most contemporary energy studies perpetuate a limited understanding of energy use; (2) elaborate upon how this understanding can be expanded, within the context of a discussion of the evaluation of the concept of sustainable development; (3) discuss the consequences of this in terms of fossil fuel use; (4), point to how alternatives solutions may, in fact, be reached. The central argument is that a shift in global energy systems is not only possible and desirable, but may well be inevitable.

In order to support this argument, the paper will be dived into three sections: (1) looking at the basic nature of energy itself, as a biophysical phenomenon, a socio-economic phenomenon, and a socio-political phenomenon; (2) the manner in which current energy systems are shaped by a dependence on fossil fuel use, which leads to high social costs, high environmental costs, and rising security concerns; (3) the emerging renewable energy system will be looked at within the context of basic energy traits, as well as how these traits can be applied to a new 21st century energy system. In all this, it will be concluded that, even though modern analysts insist upon a continued role for fossil fuels, an energy system based upon an extended study, reveals that the next inevitable transition to a renewable resource based energy system is both feasible and desirable.

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Chapter One

"Introduction: Establishing an Expanded Energy Analysis Framework"

A. Introduction

One of the most important issues concerning social development and technological progress is, and always has been, that of energy use. Any salient study that begins from this premise must inevitably attempt an incredibly complex and multi-dimensional analysis. Unfortunately, all too often, the methodologies employed to examine issues embedded within contemporary human energy systems become limited to restrictive and one-dimensional studies. Consequently, an in-depth understanding of even the basic aspects and implications of energy use is often lost. No better example of this exists than that which is found within the present-day dependence on fossil fuels and, subsequently, attempts to address the myriad of social, political, economic, and ecological problems that stem directly from the burning of these fuels. A limited or restricted understanding of energy use not only camouflages these many diverse (but interrelated) problems, it also serves to prohibit an awareness and acceptance of alternative solutions - most visibly, it limits the modern debate regarding the feasibility of renewable energy sources.

This thesis begins with an examination of the various multifaceted issues facing human energy use, illustrating the contention that the theoretical framework upon which modern energy studies are built must be expanded. Accordingly, it is maintained that a comprehensive study of modern energy systems and, similarly, modern energy use, which employs more than the standard one-dimensional analysis.

will help to explore many currently overlooked problems, as well as the interconnected foundations of these same problems. Consequently, it is argued that any attempt to develop policies pertaining to the notion of social development, when maintaining a focus on energy use, must begin from this starting point. The primary goals of this thesis are, therefore, to simply: (1) illustrate the manner in which most contemporary energy studies perpetuate a limited understanding of energy use; (2) elaborate upon how this understanding can be expanded and then discussed within the context of an evaluation of sustainable development; (3) depict the consequences of this in terms of modern fossil fuel use; (4) point to how alternatives solutions may, in fact, be reached. The central argument is that a shift in global energy systems is not only possible, but may well be inevitable.

In order to support these goals, this paper will be dived into three sections: First, a brief examination of the current shortcomings found in development studies will be presented. It will be argued that energy use cannot be adequately envisioned by these studies because of their need to limit and externalize necessary aspects of information from within their theoretical framework. As such, the basic nature of energy itself will be expanded upon: as a biophysical phenomenon, a socio-economic phenomenon, and a socio-political phenomenon. Accordingly, a study of both thermodynamics and energy systems themselves will be discussed, so as to demonstrate how energy use must be thought of in both a physical and social context. This will help establish that energy systems are far more complex than modern analysis demonstrates and, if this complexity is not respected, many unforeseen problems may arise.

Second, the manner in which current energy systems are shaped by the perceived necessity for fossil fuels will be examined. Here, the social cost of this use, the environmental cost of this use, and the rising security concerns, which result from threats to the health and safe living conditions of human populations, will all be considered to be strong reasons for reconsidering the apparent need for fossil fuel consumption. In doing this, a relevant and contemporary example will be provided as to how energy systems generate many complex issues for consideration and, subsequently, how these complex issues can create problems if not addressed properly.

Third, the emerging renewable energy system will be looked at within the context of basic energy traits, as well as how these traits can be applied to a new 21st century energy system. In all this, it will be concluded that, even though modern analysts insist upon a continued role for fossil fuels, an energy system based upon an extended study, which incorporates currently ignored environmental and social costs, reveals that the next transition to a renewable resource based energy system is both feasible and desirable. That being said, it is now time to examine the large body of literature that investigates this subject matter.

B. Literature Review

Attempting to understand the implications and impetuses of energy use, in terms of the environmental implications, is an enormous topic in modern academic literature. In fact, the subject matter is now so large that essentially every academic field must address this phenomenon in some manner or another - be it on a social (see

Elliott, 1997; Harper; Lovins, 1998), economic (see Rogers, 2000; Morgan, 1999; Gottinger, 1998), historic (see Ponting, 1991; Pacey, 1990), or biophysical level (see Umana, 1981: Cook, 1976). This is subject that has been addressed in almost countless ways, through assessments that study everything from the environmental and physical implications of energy conversion / consumption (see Georgescu-Roegen, 1982; Cooper, 1982) to the complicated social structural relations which determine the use of any given energy source (see Smil, 1991: Smil, 1997). In all this, however, most of this work has ultimately focused on a relatively narrow analytical scope and has, therefore, not endeavored to incorporate all of the many intervening factors that effect energy use.

For example, a brief evaluation of modern oil analysis shows that this energy source can be looked at in terms of market development (see Reed and Fesharaki, 1989; IEA, 2000), the availability and security of supply (see IEA 1995; Vouyoukas, 1996; Maull, 1980; Krapels, 1980), the geopolitical concerns of oil production / consumption (see AI, 1997; Conant and Gold, 1978; Yergin, 1991), or simply the manner in which oil maintains various social infrastructures (see IEA 1995a; OECD, 1999). Of course, there are many other ways in which oil can also be studied, but the point that must be understood here is that an examination that incorporates all of the many interrelated factors of oil use, because of the complication involved in such a huge endeavor, is rarely undertaken. Nevertheless, as is pointed out by environmentally sensitive studies concerned with critically expanding modern development thought (see Commoner, 1990; Mishan, 1993), understanding the vast consequences of energy use requires much higher degrees of complexity, so as to include information that has been externalized from the popular theoretical scope that is most commonly employed (see Baumol. 1979).

However, it can be argued that any academic study, in the interest of clarity, must reduce complex subject matter in to smaller sub fields; it is specialization that essentially provides the very basis of modern scientific study. Put simply, this position maintains that it is only possible to acquire useful and accurate information from within well-defined, field specific, scientific parameters (see Dove and Kammen, 1997). For instance, when applied to energy studies, this argument would maintain that it is not possible for an oil and gas chemist to fully understand the social and political implications of energy use in the developing world.

Herman Daly and John Cobb Jr. (1994) touch on this idea, when developing a critical notion of academic knowledge. They argue that the level of abstraction and specialization involved in establishing a concentrated field of study make alternative understandings of the same subject matter a non-reality. For example, they state that,

> Once socialized into the guild, relations with other members of the guild are far more comfortable and satisfying than those with outsiders. There is wide range of common assumptions that express themselves also in shared values. In this way the external threat to these assumptions and values is minimized. The result is, of course, that what has come to be assumed within the discipline appears self-evident and in no need of critical analysis. (p.34)

Unfortunately, as has been mentioned, understanding the application and consequences of energy use, in a social development context, requires knowledge of multiple factors, which fall outside the perceptual realm of specific sub fields, or disciplines, of study (see Debeir *et al,* 1991; Tenner, 1996). Clearly then, by not incorporating this realization into the study of energy many problems that result from these same factors will then also fall outside the perceptual realm of energy studies in general.

That is not to say that no one has taken a comprehensive look at energy use. Rather. some authors. such as Debeir, Deléage. and Hémery (1991), have developed very informative systemic analyses that build upon the notion of energy use, as an aspect of a larger energy system, that must include a variety of analytical points. such as social relations, biological necessities, technological knowledge, and environmental cues. In this, energy is not understood as simply being a neutral and physical element, but is a social and organic one as well (see Smil, 1994; Odum 1971). Such analyses, are deeply rooted within historical, anthropological, and political fields of thought, relying heavily on an interpretation of social development that primarily occurs around the need for and use of energy (see Flavin and Dunn, 1999; Commoner, 1979). Subsequently, the theoretical framework of these studies provides an excellent basis upon which comprehensive investigations can be built.

The danger here, however, is to fall into the same "reductionism trap" mentioned above by over-compensating and equating energy needs to those of an undifferentiated and universalized interpretation of social needs (see Debeir *et al,* 1991). Energy studies have a tendency toward becoming far to deterministic in their approach, seeing energy as the predominate factor in social development. As such, they manage to place the concept of energy use within the expanded notion of socio-structural and socio-environmental relations but, at the same time, become over reliant upon this same framework. This holds especially true for studies centered upon the "ecological laws" of the world and the effects that these laws have upon the development of social structures and energy consumption (see Bookchin, 1990; Moran, 1999). As Debeir *et al.* (1991) point out, this ecological "method, however innovative, cannot account for the social conditions in which these technical choices [over energy use] are made and, more important, leads in its dogmatic version, to the reduction of human history to the simple operation of energy laws" (p. xiv).

Nevertheless, establishing a concept of energy needs that includes both social and environmental features, on top of the simple application of the energy source itself, must be understood as an essential first step to envisioning an energy path beyond the predominate approaches. That being said, the notion of alternative approaches to energy development (see Brown, 2001; Flavin and Lessen, 1994), where concepts of social development are expanded upon so as to include environmental and social disparity issues, is a necessity that many authors have anticipated in recent years (see Sachs *et al,* 1998). It is in this vein that much of the work critical of western development models has run (see Korten, 1999). For instance, authors such as Mary Clark (1991) argue that, even though it is believed that western models for social development can solve economic and social problems, this notion is built upon a basic and somewhat fallacious understanding of social wealth. The western model referred to here is one that stems from the development of classical (and thereby neo-classical) economic thought where authors, such as Adam Smith (1976), predicted that the physical and moral health of a nation was dependent upon the ability to create wealth. This wealth was to be created through an ever-expanding industrial process, which was free from illegitimate obstructions, such as government control. Subsequently, once widely accepted, the concept of unlimited economic growth became the source upon which social health and stability were thought to depend - it became the cure of all that ails (see Alonzo Smith, 1993)[1].

Along this same line, others, such as T.R. Malthus (1989), or the early Physiocrats[2] (see Fox-Genovese, 1976), maintained that it was land and the physical laws of the universe, and not industrial machinery, that produced the surplus of material needed in wealth creation. But, here, machinery and the industrial process were still needed to transform the raw materials, from the land, into commercial goods for sale on the market. Even others, such as David Ricardo (1971), saw that a mixture between specific geographic (land) characteristics, specific cultural characteristics, and specific industrial processes, all served to create a nation's wealth through an understanding of their specific comparative advantage[3].

In all this, the most prevalent constant was that industrial prosperity was envisioned according to a split between a commercial process and the physical laws that apply to matter (see Christensen, 1989). The biophysical elements of this process

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[1] "The Practice of medicine may require the prescription of an addictive stimulant for the sake of good health. The amount of the stimulant is finite and limited by the end. When, however, one takes a stimulant for its own sake, the desire for it becomes infinite since it is no longer limited by a final goal but is an end in itself. The same is true of the output of the economic process which, rather than being used for the sake of achieving the final goal of life, tends to become the goal itself." (Alonzo Smith, 1993, p.215)

[2] According to Richard Hooker (1996), the "Physiocrats took Issac Newton's idea that the universe was mechanistic and applied this mechanistic world view to the social production and distribution of goods and services. They examined the phenomenon of mercantile economics—mercantilism is the distribution of goods with the calculated goal of achieving profit—and argued that the distribution of goods operated under the same mechanistic and natural laws that the rest of the universe operated under. Enlightenment thinkers had been busy applying mechanistic thought to other areas of social organization, so it seemed quite natural to apply these principles to the economy."

[3] The principle of comparative advantage states "the gains from trade follow from allowing an economy to [specialize]. If a country is *relatively* better at making wine than wool, it makes sense to put more resources into wine, and to export some of the wine to pay for imports of wool. This is even true if that country is the world's best wool producer, since the country will have more of both wool and wine than it would have without trade. A country does not have to be best at anything to gain from trade. The gains follow from specializing in those activities which, at world prices, the country is *relatively* better at, even though it may not have an absolute advantage in them." (see WTO, 2002)

were relegated to a simple understanding of material conversion, via the input of matter, based primarily upon the phenomenal increases to energy efficiency that the fossil fuels brought about (see Ayres, 2001): the material output, or waste, was not considered an important factor of this process (see Goodland, 1996). On the other hand, the commercial process was defined by the output of commercial goods, produced by this efficient increase to energy conversion, which then led to wealth creation (see Daly, 1996); the material input, in terms of real cost, was highly undervalued in this process (see Hubbert, 1993). The significance here, this split has become deeply entrenched within contemporary economic logic (see Kula 1998). Accordingly, modern development practices call for an industrial infrastructure, and the consumption of large amounts of fossil fuels to support this infrastructure, so as to create the wealth needed for further development within any given nation - especially in the developing world (see Fesharki, 1999; Pachauri, 1999).

The theorists who are critical of this approach, however, are quick to point out that this is a dangerous mode of thinking because it fails to recognize the environmental destruction and social disparities that escape this analytical vision (see Hawken *et al*, 1999; Tietenberg, 1998). Building on this, it is argued that the dominant western ideologies concerning development stem from simplified assumptions regarding human needs and rights (see Cobb, 1993). It is also argued, as was mentioned, that the social structures needed to meet the demands of this development model can only be realized through institutions that demand constant growth in production and, thus, an ever increasing level of energy consumption (Mackenzie, 1992; Cook, 1971). The problem is that these mechanisms of growth and development then operate in such a way that they simplify the social understanding of the relationship between economic activity, the natural environment, energy use, and human action (see Huu Dung, 1992). This over simplification serves to hide many of the negative consequences of western development models (Costanza *et al*, 2001). Herman Daly (1996a) refers to this as the development of externalities. Most significantly, what this centralized model ignores is that resource consumption and energy production can occur on a relatively decentralized and environmentally benign level – as is with renewable resources (see Ayres 2001a; Dunn, 2000a).

It is on this point that many ecological economists challenge modern development approaches and, subsequently, the resulting energy consumption practices (see Cleveland *et al*, 2001). Most notably, the notion of ecological economics disagrees with the neoclassical socioeconomic model that simply sees the economic process as being a closed relationship between material input and commercial output (see Deblonde, 2001). Rather, an ecological economic model attempts to incorporate other aspects, such as environmental degradation, ethical concepts, human rights, and the biophysical nature of an energy flow (see Heijungs, 2001; Sagoff, 1988). As Herman Daly (1996b) argues, the economic system is merely an open subsystem of a larger biophysical system. Accordingly, it is essential to understand that this subsystem cannot be maintained and, thus, continue to grow, through the simple introduction of matter and the discharge of commercial goods. In this, Nicholas Georgescu-Roegen (1982) brilliantly elaborates upon the notion of entropy, in order to describe how once matter, and thus energy, is consumed. He also explains how this matter and energy is then also transformed to a non-usable state.

The importance of this is that entropy is a process, which has far reaching implications for the entire biosphere. In economic terms, the wealth of energy resources is depleted if the regeneration rate of these resources is lower than the consumption rate (Ayres and Nair, 1984; Chapman, 1974). This process also has spill over effects, or externalities, that can damage several biophysical processes on the planet (see Daly 1999). Ecological economists, thus, argue that protecting against these problems requires that energy consumption be understood in the larger context, as being both biophysical and social (see Duchin and Lange, 1994). Much of the recent work done on developing the notion of natural capitalism and sustainable development focuses on this basic assumption (Dorf, 2001; Brown, 2001).

For example, authors such as Walter Manshard (1998) systematically look to the many ecological aspects of the natural world and the vast diversity of negative consequences that economic behavior has produced. From this, attempts to develop a biophysical basis for restructuring global economic and political policies, so as to defend the earth's natural environment, are put forward (see Holmberg *et al*, 1996). Subsequently, the interconnected characteristics of the planets ecological "subsystems" - the geosphere (solid earth - rocks, minerals, and continental plates), the biosphere (the area of the planet in which life exits), lithosphere (the upper layers of solid earth - approximately 50 miles in depth), the hydrosphere (water), the atmosphere (air and other gases), the pedosphere (soil), and the cryosphere (frozen land and water) - are all depicted as being intimately interrelated, where change to one will produce change to many. For example, Tatsushi Tokioka (1997) systematically describes the negative consequences that occur within the earth's ecological systems during the process of global warming. To do this he provides an excellent "three dimensional atmospheric model" (p.63), which clearly depicts how climate change stimulates a direct and indirect chain reaction throughout every ecological system affected by climate. Along this same line of reasoning, R.K. Pachauri and Rajashree S. Kanetkar (1997) identify the manner in which development and energy needs in the developing world have led to increasing rates of both deforestation and desertification. Using the same concept of a chain reaction, they show how the primary causes of "deforestation and desertification, though distinct, provide mutual feedbacks and are far from being independent of each other" (p.79).

That being said, energy analysts who attempt to understand the biophysical elements of energy use, and the subsequent ecological effects, are clearly taking an essential first step toward redefining energy studies in a broader and more accurate manner. The implications of this, in terms of energy use and the principles of sustainable development, are that when energy resources are produced or consumed the effects that this consumption has on all ecological subsystems must be measured - good and bad (see Kaya, 1997). Not considering this simply provides an inadequate gauge for the economic benefits of energy use, not to mention a method to systematically ignore environmental damage (see Flavin and Dunn, 1999a).

With these basic realizations, ecological economists have developed extensive and highly technical depictions of how energy costs must be understood in terms beyond standard economic thought (see Lovins and Lotspeich, 1999; Weizsäcker *et al*, 1997). They suggest that the various direct inputs, such as labour and investment, and the various indirect inputs, such as the solar energy that stimulate the photosynthesis process, must all be considered when thinking of energy costs. This argument further suggests that the current energy pricing mechanism cannot adequately reflect the importance of the many different elements surrounding human energy use (see Flavin and Lenssen, 1994).

Given this, even though modern development is primarily driven by economic concerns and, consequently, modern energy use is measured in standard economic terms, these indications cannot be considered the only factors in energy choices (see IEA, 1997b). Put simply, the reason why energy systems experience change, or transition, can depend on many different incentives (see Debeir *et al*, 1991). In some cases, resource scarcity and supply security force governments to look into alternative energy production methods. The Japanese desire, based on their extremely resource poor status, to develop nuclear and renewable energy technologies serves as a good example of this (see Okamatsu, 1997). In other cases, technological advancements allow old production methods to once again play an increasingly important role. Debeir *et al.* (1991) refer to this as technical elasticity. The recent advancements to wind power technologies illustrate this point well (see Flavin and Lenssen, 1994; Brown, 2001). And, in even additional cases, ideological predispositions determine energy use choices. David Nye (1999) points to this by analyzing the difference between American energy consumption and European energy consumption patterns. He argues that the American predisposition toward the drastic over-consumption of energy is deeply rooted in their cultural ethos, which makes it very difficult to change (see Nye, 1997). These factors are most evident when comparing American notions of unlimited energy consumption to the slightly tamer European nations, which adhere to an inherent sense of limits (see Nye 1999).

In all this, political theorists, such as Dennis Pirages (1978), argue that the most pressing political issue surrounding these choices is the lack of a viable alternative for the industrial complex to turn to in the event of the current system failing. The perceived lack of an alternative justifies many of the complex geopolitical concerns, facing energy uses, which are noticed in modern international political systems (see Yergin, 1991). It also contributes significantly to the wide spread support for the current fossil fuel system. In fact, mainstream energy projections routinely cite the economic and technical superiority of the fossil fuel infrastructure when justifying further developments (see OECD, 1999). Notably, the ability to support an income generating industrial capacity is recognized as the most important element of energy development when looking at new projects (see IEA, 1995a). As such, it is the fossil fuels that garner the overwhelming majority of industry and governmental support when choices concerning energy production and consumption are made (see Cassady, 2001; GSC, 2002; FOE, 2001).

However, when analysts incorporate the additional costs associated with energy production, such as environmental degradation, the choice no longer seems as obvious. James J. Mackenzie (1993) demonstrates this when he states that traditional notions of energy choice and transition will not apply in the 21st century. He argues that notions like scarcity, cost, and convenience are not expected to be a significant factor in energy system studies throughout the next century (see Flavin and Lenssen, 1994; Flavin and Dunn, 1999). Rather, the immense environmental damage that is caused by fossil fuel use, the rising social costs associated with the fossil fuel infrastructure, and the geopolitical security concerns that develop according to fossil fuel reserve availability, will all provide the impetus for a shift toward renewable energies (see Mackenzie, 1992).

Making such a prediction at this point is clearly just that, a prediction. Nevertheless, an overall examination of the vast amounts of literature published on the fossil fuels, from both a critical and non-critical perspective certainly does offer evidence that would seem to support this contention (see OECD 1999; Davison, 1989). Even conservative estimates, that maintain the predominate system of analysis, have recognized that the externalities produced by fossil fuel consumption will require drastic change in the near future (see Imboden and Jaeger, 1999). However, it is also understood that much of the changes envisioned by these conservative estimates, will come in the form of improvements to fossil fuel conversion techniques (see IEA, 1997; IEA 1997a). This is evidenced by the desire of most industrial nations to invest in energy efficiency technologies (see IEA, 1991; IEA 1996; IEA 1997c). The principal reasons for these changes, as they remain within the realm of fossil fuel use, are the perceived threats to the economic process and social security within industrial nations (see Clawson, 1995). Most significantly, it is widely believed that shifts away from fossil fuel use, as understood by mainstream economic logic, will bring about constraints upon commercial endeavors that may, in turn, slow growth rates and reduce the general wealth levels within any given nation (see IEA, 1995a).

An excellent example of this can be found in a report published by the American economic think tank CONSAD. and their critical assessment of the Kyoto treaty. In this, CONSAD argues that reducing energy consumption (thereby reducing fossil fuel consumption) would endanger American interests in the form of "employment, economic output, and standard of life for working families, senior citizens, and those who live on fixed or low-incomes" (CONSAD, 1998)[4]. This is a belief that is commonly found amongst the industrial and political elite of the industrialized nations, to varying degrees, as is supported by the various energy policies aimed at reducing fossil fuel use (see IEA 1996a; IEA, 2000). As such, the political support found in many industrial nations, especially those in North America, remains strongly focused upon fossil fuel production and consumption (EIA, 2001; Canada, 2000; EEA, 2001).

With that being established, it must be recognized that a growing body of literature is now beginning to critique the consumption of fossil fuels (see Dore and Mount, 1999; Bejan *et al*, 1999) and, subsequently, continuing the serious search for alternative approaches (see WB, 2000; Tellam 2000). The primary point of contention in this comes from a return to the biophysical argument advanced by ecological economists and the belief that renewable resources are capable of generating the necessary energy to meet social needs (see Rogers Jr., 2000). According to some authors, the vast environmental and social consequences that arise from the use of fossil fuels must now be understood as a serious threat to the

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[4] The extent to which this report influences the American policy position can be seen in how US President George W. Bush commonly uses the information and claims found within it so as to defend his own claims toward supporting the use of fossil fuels in order to protect American interests. (see US NEPDG, 2001).

economic, social, and environmental health of the planet's populations, not to mention the physical well-being of the planet itself (see Myers and Kent, 2001; Davison, 1989). In addition, the political contention that energy security depends upon further access to the fossil fuels is also being challenged upon this front as well. It is argued, rather, that the problems that arise from fossil fuel use will actually cause more threats to security in future than they prevent (see Mackenzie, 1992; Bromley, 1999; NRDC, 2001; UCS, 2001).

In this, coal is seen as one of the most damaging energy sources of the modern age (see CA, 2001). Its fuel cycle results in extensive environmental problems that not only harm biophysical processes, but also the economic activity that depends upon these processes (see Myers and Kent, 2001; NRDC, 2001a). The health threats, which result from pollution, are also understood as being very serious. Oil and natural gas are also now being described along these same lines. The pollution and environmental consequences that these energy sources produce are extensive and very dangerous to multiple aspects of life on planet earth (NRDC 2001b; NET, 2001). Finally, the development of a nuclear alternative, which is seen as an extension of the large and centralized fossil fuel infrastructure, is challenged by critics and as being incredibly threatening to the environment, social health, and the establishment of stable energy security policies (Williams, 1998; Knelman, 1999). These same critics are now interpreting the continued political and industrial support of the fossil fuel and nuclear energy systems, as a position that can only lead to dangerous levels of biophysical damage (see WRI, 2000). In short, the need for an alternative system is increasingly understood as being more and more necessary every day (see Flavin and Lenssen. 1994; Brown. 2001).

The alternative energy system. which is now advanced by both the ardent critics of the fossil fuel energy system and the proponents of economic growth. is centered upon the development of renewable energy sources (see Boyle 1996; IEA. 1997d). There is, nonetheless, a great deal of disagreement over the viability of these sources, and the time frame in which they can be applied, but there is no disagreement that they will become the predominate energy source of the future (see Cassedy, 2000; IEA, 1994); once the renewables are examined according to this growing commercial and technical feasibility, their possible use in the future becomes blatantly apparent (see Flavin and Dunn, 1999).

An examination of the renewables shows that they are all currently experiencing very exciting gains within their technical and economic capacities. Most notably, wind energy (see Kahn, 2000; Kufahl, 2000), solar technologies (see Flavin and O'Meara, 1998; Harmmonds, 2000) and the hydrogen fuel (see Dunn 2001; Dunn 2000) are all presently experiencing remarkable improvements. As such, the extensive use of these energy sources could occur much sooner than is expected (see Ayres, 2001). In understanding this, the vast development strategies currently surrounding the fossil fuels seems ill advised at best. Failing to foresee this could be damaging on many fronts, such as economic, environmental, geopolitical, and social necessities (Ayres, 2001a). Therefore, the development of an energy systems analysis, which can incorporate the many factors that currently lay outside mainstream studies, will be an incredibly beneficial first step - for both human beings and the planet itself.

C. Building the Basis for an Expanded Energy Framework

Establishing a framework for adequately studying the complexities of energy use is an overwhelming immense endeavor. In fact, the need to incorporate the many different factors, which all play a role in the development and maintenance of modern energy systems, pose a significantly difficult task for any researcher interested in the subject. This is especially true in the field of Political Science, where the notion of energy systems remains an under-developed reference point, which, all too often falls victim to the need for simplification. Subsequently, as was mentioned, many of the necessary elements that effect any given energy study are not given due consideration. Critical notions such as energy determinism, resource exhaustion, and the global security threats to energy supplies are, therefore, developed without first establishing a systems based analysis that can understand additional, but mutually dependent, issues. Correcting for this under-developed notion of energy systems must thus be the first step toward re-envisioning a comprehensive framework for energy studies.

It is simply this first step that will be the overall guiding framework for the following thesis. As such, a newly developed framework will not be established but, rather, the problems within the current system will be critically assessed. The study attempted here must, therefore, be understood as a complement to modern methodologies and not a substitute. This way, assumptions made concerning social development and energy use can be questioned so as to re-evaluate their importance. Subsequently, it is hoped that alternative, or externalized, concepts will be introduced into contemporary frameworks in order to further elaborate upon them, rather than disregarding them.

In all this, it is anticipated that: (1) modern energy systems can be properly appraised in their entirety; (2) externalized problems, such as environmental and social costs, will be given appropriate deliberation; (3) the necessity and avenues for change will be revealed. In the end, this study will "open the door" for additional investigations into energy that build upon the expanded framework discussed here. Put simply, this thesis will endeavor to establish a starting point from which future studies into the problems associated with fossil fuel consumption, and need for renewable energy development, can commence - a foundation that fully incorporates environmental and social issues within its governing dictates.

Chapter Two

"Understanding Human Energy Use Through a Systems Analysis"

A. Introduction

Attempting to understand both the social and the physical nature of energy requires an in depth knowledge of human energy systems, as well as an awareness of how these systems operate on multiple levels. And yet, many of these levels have been virtually ignored by popular western thought. Why? To explain this, the following chapter will now turn to the ideas advanced by ecological economists so as to investigate the conceptual limitations found in popular social development models. Namely, the popular notions of a "level" or "standard" of development will be examined according to the ecological criticisms levied against the mainstream perceptions that currently legitimize the notions of "modern" development.

In this, the conceptual environmental poverty that exists within these models can be studied. As a result, investigating the weaknesses, in terms of a balanced design, within contemporary energy system developments will then become possible. Building on this, the notion of energy systems will be discussed at length, so as to demonstrate how they are indisputably composed of both social and environmental processes. Subsequently, it will be shown that a continuous flow of energy is essential to the survival of any given system.

Unfortunately, as will be established, the fundamental concept of a continuous energy flow also falls victim to a limited conceptual framework; this is because of the fact that energy systems generally become dependent upon a limited number of finite sources. To further develop this idea, the notion of entropy will be introduced so as to explain the dangers and limitations, both social and environmental, of relying upon finite energy sources. In the end, it will be argued that the problems associated with entropy, and ignoring basic energy system realities, can lead to energy use impediments, which must inevitably be addressed. From all this, an expanded critical agenda for looking at the problems of fossil use will ultimately be established. That being said, it is now time to examine the conceptual limitations found within modern developmental theories.

B. The Limitations of Modern Social Development Frameworks

There is no better example of where the narrowly defined epistemological vantage point for social development and energy use can be made apparent than as it is found within typical theories of modernization. Popular conceptions of the *modernized world*, and its historical developmental process, are rooted within an implicit assumption that "describes two types of social structure[s]" (Larrain, 1989, p.87) that are historically connected through a particular social evolutionary process. This is a process where "all societies follow a similar historical course which gains in differentiation and complexity as it departs from one polar type and moves toward the other" (ibid, p.87) through a necessary evolutionary process.

It is this idea that clearly demonstrates the fundamental basis of modernization theories, where it is argued that *traditional societies* (one of the structural poles) progress through a process of transition toward becoming a *modern society* (the opposite structural pole). Thus, the modernization school of thought contends that proper social development must follow a particular pattern and adhere to specific structural laws - there is one best way to develop (see Parsons, 1977; Parsons, 1951). Accordingly, it is believed that any development attempts that do not follow these structural laws will inevitably result in an inferior or substandard *level of development*; this is an argument that limits interpretations of development to temporal definitions where "stages" or "levels" of socio-political organization must be achieved along the evolutionary path to proper development (see Huntington, 1968). Hence, the popular idea that underdeveloped countries are backward or behind.

Therefore, it can be stated that the principal concern of modernization theorists is to identify the complex pattern of situational experiences that must be adhered to, or replicated, if an acceptable standard of development is to occur (see Inglehart, 1997; Palmer and Stern, 1971); arguably, a concern even more prevalent in the age of globalization (see Roberts and Hite, 2000). It must be recognized here, however, that the objective of identifying a single social transformational pattern is not a new concept in social thought. In other words, this is not solely the intellectual domain of modernization theorists. Rather, it is a notion that has a long history in socio-political theory and has been covered through many sociological, psychological and political postulations. Most socio-political theorists cultivate an idea as to what the best motivations and goals for social development should be. On this account, social theorists critical of modernization models also attempt to envision a procedure through which society must transform itself in order to achieve the desired "higher" level of socio-political development (see Dube, 1988; Taylor, 1979).

The transformation processes, referred to here, however, is almost always rooted in a detailed conceptualization of multifaceted human nuances - such as social, structural, biophysical, and psychological interactions - that must be conceived of as a part of this transformation process - all of which are too complex to discuss at length within the scope of this thesis (see Mander and Goldsmith, 1996). What can be argued here, nonetheless, is that modernization theories depart from this tradition in the sense that they "believe in the continuity and unidirectionality" (Larrian, 1989, p.86) of a social developmental process, which is dependent upon structural concerns and, thus, abstracted from the many nuances of human interaction. And, for modernization theorists, these structural concerns are generally confused with a predetermined perception of human decision-making processes that are predominately influenced by economic criteria and technological goals (see Hetzler, 1969). That being said, the stimuli that help this confusion to occur will now be examined.

Free Market Mechanisms and Economic Growth

This confusion becomes obvious when we look at the epistemological vantage point of free market principals and market mechanisms. For example, it cannot be denied that within the current context of socio-cultural development the "predominate institutions influencing decision-making are market forces and market-based mechanisms" (Opschoor, 1996, p.328). This is an institutional arrangement that has continuously grown in popularity since the initial stages of the industrial revolution but recently has found unprecedented support in the post-second world war arena (and even more so in the post-Cold War era).

John B. Cobb Jr. demonstrates this point when he argues that the "most important change in the global order" after the Second World War "was the shift from a primarily political world system to a primarily economic one" (Cobb Jr., 1995, .84). This shift to an economic order was clearly expressed at the Bretton Woods conference in 1944 where global financial institutions, such as the International Monetary Fund (IMF) and the International Bank for Reconstruction and Development (the World Bank) were created. These new institutions, along with international trade agreements like the General Agreement on Tariff and Trade (now the World Trade Organization), ensured that the world's capitalist nations would now co-operate "for the sake of the growth of the global economy" (ibid, p.84).

In other words, the concept of economic growth now became synonymous with an ideal of global prosperity; this is apparent in the explicit goal of Bretton Woods to "increase the rate of economic growth globally" for it was assumed that "global economic growth benefits all" (ibid, p.84). Although original Keynesian principles (see Keynes, 1974), such as establishing a social welfare state and the institutional protection against business cycle downturns, are no longer predominate, the fundamental faith in economic growth, and the market mechanisms used to create this growth, remains entrenched stronger than ever before. For proof of this, one need not look any further than the 1996 ratification of the Uruguay round of GATT negotiations, where the World Trade Organization (WTO) was established in order to further promote the goal of unfettered global economic growth (see Das, 1998; Faini and Grilli, 1997). It can therefore be stated that socio-developmental goals are currently dominated by this globalized-economic ideology.

The obvious problem here is that social goals that transcend these economic growth imperatives, as they are found within the guise of free market ideologies, are completely neglected when social developmental goals are perceptually predetermined by the operation of the free market. Hazel Henderson (1996) refers to this as an intellectual approach that is inherently restricted by "mainstream institutional blinders" (p.32), which serve to disguise any alternative developmental solutions. The implications of these blinders, as they are found within the contemporary dictates of global political structures, become blatantly apparent when one looks to the notion of ecologically sound or environmentally sustainable development.

Sustainable Development

Concepts of *sustainable development* are ones "related to the continuing existence of conditions favorable to life, human life in particular" in a way that is fundamentally associated with "fairness or equity, and to the integrity of natural systems and process as perceived by *Homo sapiens*" (Opschoor, 1996, p.328). They are, therefore, concepts that are intimately associated with the conceptual realm of human behaviour, where cultural development is understood as an attempt "to integrate social factors and goals with long-term economic and ecological ones," thereby "striving for the 'co-development' of society and the environment by actively restructuring the economy according to both ecological and equity criteria" (Sagasti and Colby, 1993, p.183). The principles of sustainability are then ones that implicitly recognize the value of human perceptions over social life, as it is intrinsically interconnected with the natural world. In this context, developmental motivations must thus consider the ecological impact of human behavior in a manner that acknowledges the mutually sustaining relationship between the human race and the global environment (see Baumol, 1979; Commoner, 1990). It is not enough to simply depict the quality of human life according to economic definitions.

Francisco R. Sagasti and Michael E. Colby (1993) recognize this when they identify the socio-managerial concept of *Eco-Development*. Here, the principal social goal is to design "human society with its environment for the benefit of both using the self-designing ecosystems as a primary tool - rather than economizing and engineering ecology" (p.183). This concept is in stark contrast to the socio-managerial ideology of *Frontier Economics*, which contends that "[n]ature is conceived as a mechanism that exists to serve humans, and subject to improvement by them, or as an adversary to be conquered" (Sagasti and Colby, 1993, p.182). Unfortunately, it is this idea that has served to support the social evolutionary notions found within modernization principles.

So, in order to recognize managerial conceptions, such as Eco-Development, a dramatic reinterpretation of the human relationship with the environment is required. In this reinterpretation, the ontological definition of nature must begin from a conceptual starting point that understands how the natural environment mutually reinforces the stability of human life systems. However, the current institutional framework of free markets cannot make this reinterpretation since they are driven by the goal of efficiency to an extent that all other values and goals, such as equity and sustainability, are generally excluded. This is a problem that directly results from the failure to effectively recognize any alternatives to economic development, which is a failure that demonstrates the powerful nature of free market *institutional blinders* (see Henderson, 1996).

Externalities and Spill Over Effects

The inability to identify alternatives to free market development stems largely from a circumstance that Herman Daly and John B. Cobb Jr. (1994) call *misplaced concreteness*. They argue that the dilemma of misplaced concreteness arises when particular forms of knowledge are applied to the "real world" so as to make conclusions about reality "without recognizing the degree of abstraction involved" (p.25) in the process of acquiring this knowledge. What they are referring to here is a method of study, which takes place within most mainstream academic disciplines, where specific subject matter is abstracted and observed separately from its relationships to any other phenomena. Knowledge within these various disciplines thus develops according to a highly refined understanding of particular aspects of the physical and social world but fails to consider the how various elements of cultural and natural life are, in fact, interrelated. Subsequently, the failure to identify how these elements are interconnected only leads to a superficial understanding of any given topic, therefore allowing for the *fallacy of misplaced concreteness* to develop, where people neglect to recognize "the degree of abstraction involved when an actual entity is considered merely so far as it exemplifies certain categories of thought" and thus "draw unwarranted conclusions about concrete reality" (Daly and Cobb Jr., 1994, p.36).

When applying this argument to the concept of free market mechanisms and economic development it becomes obvious that market based measurements for development are not exempt from making these same mistakes. For example, most economists argue that the transactions, which occur within the competitive market place, are justified by the *virtue of mutual gain* (see ibid). It is this belief which maintains that all parties who participate in market exchange do so because "humans are motivated by self-interest, expressed primarily through the quest for financial gain" (Korten, 1996, p.185). It can therefore be stated that the virtue of mutual gain is based upon the doctrine of *Homo Economicus*, which argues that human beings are rationally motivated by decisions over the value of a given action, resource or service, as it is determined according to a complex evaluation process that "takes on a quantitative form in terms, say of monetary units" (Boulding, 1991, p.26).

According to this postulation, partaking in market transactions allows humans to rationally evaluate and meet their own individual needs while simultaneously fulfilling the needs of another, thereby contributing to the mutual gain of both parties. From this cause, it is suggested that an economic system, which embraces the principles of free market *economic liberalism* is a necessary prerequisite for successful social development, since this liberalism is thought to "spur competition, increase economic efficiency and growth, and is generally beneficial to everyone" (Korten, 1996, p.184). Furthermore, it is argued that economic growth allows more people to take part in market interaction and thus gain from these mutually beneficial actions; this is significant because it is a belief that has been firmly entrenched in the western social psyche since the Bretton Woods conference.

It can therefore be argued that a sustained state of economic growth is now understood as the foundation of human progress within mainstream developmental circles (see Daly 1996). In addition, self-interested free market transactions are believed to be the engine that drives this progress. And, to assert a contrary opinion is considered heterodox as these are tenets that have now "become so deeply embedded within our institutions and popular culture that they are accepted by most people without question, much as the faithful take for granted the basic doctrines of their religious faith" (Korten, 1996, p.184). Nevertheless, this serves as a perfect example of *misplaced concreteness* because it is a vision that "abstracts from the real world in which everything that happens has much wider effects. In fact, market transactions have consequences that are not limited to those who choose to engage in them" (Daly and Cobb Jr., 1994, p.52). In addition, market transactions produce consequences that are not only limited to human beings but have wider ecological consequences as well. Failing to consider these wider effects only limits the notion of mutual gain to a concept that can adhere to the criteria of self-interested free market operations; this is a particularly distressing limitation because it helps to foster a narrow and myopic understanding of what is individually gained by market interaction, while neglecting to consider the social and environmental costs.

To make matters worse, the negative consequences that inevitably arise from the side-effects of market behavior cannot be dealt with adequately, even if they were to be identified, since they are perceived to fall outside the main body of its methodological framework. For instance, mainstream economic thought identifies the adverse side-effects that result from market operations, as *externalities*. These externalities are understood as factors that do not contribute to the efficient functioning of market operations and must therefore be "pushed out" of its perceptual scope. Consequently, these externalities are believed to be extraneous to the market and are viewed in a manner that deserves "separate and peripheral attention" (Daly and Cobb Jr., 1994, p.53). This places obvious limitations on the capability of free market mechanisms to deal with problems that occur outside the economic sphere for the reason that they have been abstracted from their connection to marketplace based action. Nevertheless, Sagasti and Colby (1993) point out that "many nations adopt(ed) this view as a necessary but minor evil that is justified by the need for economic growth"(p.182); this is, however, a justification that is hard to make when one considers the wider effects of environmental degradation as a significant aspect of these externalities.

Clearly then, market based developmental motivations are concepts that confuse the essential relation between human beings and the environment by placing the conceptualization of the economy in an improper epistemological starting point. Furthermore, it is this starting point that hinders the developmental policy scope by concealing the notion of sustainability. What must then be done is the redefinition of the economy as it relates to the environment. To that end, the process of evaluating human action must be understood in a manner that transcends market motivations. Only then can the essential relationship between human beings and the environment be better understood.

Without doubt, one of the most significant elements of social development and human relations with the environment is the consumption of energy. Energy use is, nevertheless, popularly envisioned within the same aforementioned social development models. It is, therefore, restricted by the same economic logic and conceptual externalities as well. Truly understanding social development needs and environmental problems, however, requires a full understanding of how energy works, outside the restricted framework of modern development thought. So, in order to elaborate upon an effective energy study, that incorporates both environmental and social needs, it is now necessary to look at energy systems in their entirety.

C. Energy System Relations

One of the only truly universal characteristics that the human species shares with the remainder of organic life on planet earth is the steadfast reality that we are, in fact, a biological species. In all of our arrogant attempts to conquer and transcend the physical limits of the universe, the one thing that persistently restrains human action, and will continue to do so for the foreseeable future, is our basic genetic constitution. There is little question that human scientific knowledge has progressively developed new and fascinating ways to manipulate and mold the world around us. We have managed to have an impact on every continent of the globe and reach out into the vast expanses of space (see Boulding, 1993).

Proponents of these accomplishments quickly point to scientific knowledge as being the blessing that everyone can share. And, to an even greater extent, modern applications, combined with technological efficiency, as tools with which all problems can be overcome (see Daly and Cobb Jr., 1994). This technocratic optimism, however, that does not go unchallenged (see Georgescu-Roegen, 1986). The list of theorists who have taken it upon themselves to critique modern capitalism is long and distinguished. Likewise, those who have written on the dangers of over reliance on technology, and the scientific applications of technology, are equally significant (see Ellul, 1964). Few theorists, however, have looked to how economic and technological thought, when applied together, serve to conceal a crucial reality of human existence: the simple fact that all life "depends on a continuous flow of energy" (Daly, 1996, p.177), but that this continuous flow is ultimately subject to finite limitations.

That being said, the field of ecological economics - a sub field based on a broad critique of classic economic thought - has constructed a critique of modern economic rationalism and human energy use. This critique addresses the understanding of contemporary energy use within the context of the central role energy systems play in human endeavors (see Georgescu-Roegen, 1982). Energy consumption patterns are depicted in accordance with socio-economic structures, human needs, and environmental degradation (see Debeir *et al.*, 1991). Subsequently, the advancement of scientific knowledge, economic efficiency, and the biophysical process of the planet are all interpreted as being inevitably subject to the thermodynamic laws of energy conversion (see Townsend, 1992; Daly, 1992). Once this analysis is operationalized, perceptions of the basic limitations to human action can be placed into to a proper "policy perspective".

For instance, Tran Huu Dung (1992) observes that human biological life is rigorously dependent upon both the consumption of "useful" energy and the efficient output of "less-useful" energy (or waste). The significance of Dung's observation is that human economic life also necessarily depends upon this dynamic; any interpretation otherwise is simply fictitious and misleading. As John Peet points out, "there is no known economic process that does not begin by using some sort of raw material [or energy] and eventually [end by] generating waste" (Peet, 1992, p.219). Simply put, the "continuing transformation of available and unavailable energy resources in accordance with the Second Law of Thermodynamics is the fundamental fact of life in the functioning of all economies" (ibid, p.219)[1]. Since energy systems are so fundamental to an ecological understanding of the human economic condition, in both the national and international contexts, it is now necessary to have a brief discussion on energy systems, as well as their applications in this context.

Endosomatic Energy Systems

The one thing that human beings simply cannot change or overcome is that, as a biological species, we must sustain and recreate ourselves through a necessary interaction with the natural world - as we are indisputably an element of the natural world (see Bookchin, 1990). It must then be understood that this intrinsic and paramount relationship with the natural world serves to fundamentally define our

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[1] A further elaboration upon the laws of thermodynamics, and their relationship to ecological economic thought, will be developed in the following section of this chapter (on entropy). Nevertheless, to quickly explain: the first law of thermodynamics simply states that matter cannot be created or destroyed. In other words, it is finite. And, the second law states that matter will always move from a state of high order to low order. This means, in energy terms, that matter naturally moves from being useful to non-useful. Realizing these two laws within economic logic has vast consequences for

most basic needs as a species (see Odum. 1971). Darwin believed that every modern species. through the process of *natural selection* (see Darwin. 1996), has adopted certain traits that help them to sustain themselves through the various symbiotic relationships found within any given natural system, or ecosystem as it is now defined. These physiological adaptations, as first described by Alfred Lokta (1925), constitute the *endosomatic organs* (heart, lungs, liver, and other internal organs) and, thus, the biological composition of any given species. The most basic impetus for adaptation is always the need to assimilate and transform energy sources for genetic purposes (see Debeir *et al.*, 1991).

In this sense, it can be observed that the need to consume energy serves as the single most significant physical phenomenon of the natural world (see Smil, 1994; Smil, 1997). Conversely, however, this need must then also be considered the single most restrictive physical phenomenon of the natural world. It is upon this idea that the notion of *biological converters*, as advanced by Jean-Claude Debeir, Jean-Paul Deléage and Daniel Hémery (1991), can be introduced. These authors demonstrate that "living organisms appear as very particular 'machines', converters of one form of energy into another" (p.3); the basis of all this is the solar radiation stored within plant life.

The very best biological converters are maize and sugar beets, which manage to convert almost two percent of the solar radiation to which they are exposed (see ibid). The notion of a food chain supplies a good example of how biological converters transform and use energy sources. Of the two percent of solar radiation

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notions of unlimited growth and consumption. Most notably, an unlimited state of economic growth is simply not possible.

that is consumed by either maize or sugar beets, only ten percent is transferred to *herbivores* when they consume these same plants, and only ten percent of this ten percent will be transferred to *carnivores* when they consume the herbivores (see ibid).

In each case, the energy source, from within the energy community where this process is taking place, is transformed in order to "give way" to the next conversion. Energy can then generally "be defined as 'what must be supplied or removed from a material system to transform or displace' it" (Bienvenu, 1981; Debeir *et al.*, 1991, p.2). The biological drive toward consuming energy is clearly also dependent upon an ability to utilize or transform it. The future of humankind (as both a biological and social species) is, in the most basic sense, tied to the effectiveness with which we harness the energy that ecosystems provide (see Smil, 1994). Therefore, it is here that the first essential element of any energy analysis is made apparent: all energy relationships are inherently contingent upon a capacity for transformation.

Exosomatic Energy Systems

The significance of energy relationships and the nature of energy transformation has historically been of paramount importance to not only organic life but also the propagation of human civilizations (see Smil, 1997). In fact, as Debeir *et al.* (1991) demonstrate, the same biological drive that shapes the human need to consume energy also holds true for human societies as a whole. The distinctive character of these two drives is obviously actualized in very different ways but their fundamental purpose is very similar, demonstrable with an examination of human *exosomatic organs*. These are the "organs" that various human civilizations have developed so as to assist in the maintenance and recreation of their societies: the tools, machines, artifacts, and buildings, which are invented and employed so that human societies can sustain themselves and continue to develop (see Pirages, 1978). As such, Debeir *et al.* (1991), draw a very specific distinction between endosomatic and exosomatic organs. It thus becomes clear that,

> the great specificity of the human species, compared to the rest of the animal kingdom, is its capacity to define its own goals, independently of any genetic programme. From this arose the innovativeness of human societies in the field of energy use: the invention of exosomatic organs and a permanent quest for additional quantities of free energy to activate these tools (p.4).

In this sense, the quest for energy, or the drive to consume energy, is directly related to the social need to create and recreate the exosomatic organs of any given human civilization. The various evolutionary adaptations human societies have made to their exosomatic shells, throughout history, have thus been (in large part) dependent upon the availability of energy sources and social organization used in harnessing this energy (see Mumford, 1967). More importantly, societies have needed to transform and manipulate energy sources (for their own benefit) with ever-increasing efficiency, since growth increases demand. This can be done by either consuming higher quantities of energy sources, finding new energy sources, or making better use of the energy sources already being drawn upon (see Smil, 1991).

All of these factors, combined, can be understood as "energy-system" efficiency. The importance of this, in terms of energy needs, is that every system must maintain an efficiency level that is (at the very least) inversely proportional to the rate of consumption. Efficiency, then, requires a very particular technical "know-how", which is "subject to the sum of [the] existing knowledge" (Debeir *et al.*, 1991, p.13) base used in harnessing energy and employed by different socio-political structures. For it is this knowledge base that serves to shape the technical procedures used in energy conversion. Energy use and energy system efficiency, to a large extent, is therefore determined by the "interplay of economic, demographic, psychological, intellectual, social and political parameters operating in the various human societies" (Debeir *et al.*, 1991, p.13).

Historically speaking, this is a fact that has been evidenced ever since the time of incipient civil society (see ibid). For example, the point when human beings embarked upon the long transition to stationary communities required a series of innovations, which allowed for an ever-increasing knowledge base concerning food production and energy use (see Cauvin, 1973; Chard, 1975). This line of reasoning is founded upon recent criticisms, put forward by cultural and pre-historical anthropologists (see Debeir *et al.* 1991), levied against the famous archeologist Gordon V. Childe (1986) and his notion of the Neolithic revolution. For example, rather than advancing the idea that the Neolithic revolution "was focused above all on the emergence of agriculture and animal husbandry" (Debeir *et al.*, 1991, p.18), which is Childe's primary thesis, new historical evidence supports the notion that change occurred from incremental improvements to human technical capacities. Techno-economic evolutions, spread over long periods of time, slowly resulted in the emergence of sedentary lifestyles and a "mastery of the whole food-energy chain" (ibid, p.19) long before evidence of agriculture existed.

Simply put, the seminal shift was the attainment of technical knowledge concerning the improved ability to manipulate the energy process. The ability to maintain a sedentary lifestyle followed, along with agricultural techniques and processes. It was, thus, the improved manner in which energy was controlled, converted, and consumed that engendered civil society and social structures (see ibid). This axiomatic change is better understood in the context of the human species as an organic energy consumer: the organized and structured productive systems, and all the exosomatic artifacts that support these systems, became an essential extension of our organic energy consumption process (see Smil, 1991). It is here that the subsistence and growth of human endosomatic and exosomatic organs became mutually dependent upon each other. With that, it is now possible to look at human energy systems.

Human Energy Systems

Once human beings began to maintain a sedentary lifestyle through the control of food and energy chains, a system emerged that is centered on the organized mobilization and transformation of energy within the parameters of social, technical, political, mental, and physical needs. These distinctively unique characteristics can now be understood as human energy systems. Debeir *et al.* (1991) define this when they state, "[a]n energy system is, therefore, a structure for the mobilization and appropriation of surplus produced by the application of energy effects, whether immediate or deferred, or of natural phenomena to productive purposes" (p.7).

Important to recognize here, is that it was the ability to organize the appropriation of an energy surplus that allowed for new exosomatic structures, which were outside the scope of immediate necessity (see ibid). And, with this came a growing body of knowledge relating to the maintenance and recreation of these same exosomatic structures. Subsequently, this process then also engendered growing energy needs, which thereby stimulated social learning that was concerned with better meeting these needs. As human energy systems would grow, it became essential that the organized control over food and energy chains continued to improve as well, so as to either make more efficient use of energy stocks or to discover new energy sources (see Smil, 1991; Smil, 1997).

Thus, in the original development of human energy systems, it was the ability to invest and defer energy surplus, in the interest of future productive capacity, which allowed technical knowledge to enter into an ascending cycle. Simply put, it was the manner in which various energies, all still organic in origin, were now used that created "the conditions for the cycle of technical innovation and development" (Debeir *et al.*, p.20). The basic governing rule of an energy system, in this sense, is that the social structure must harvest more energy than it invests; it must create a surplus for future investment. For instance, any given society (or human energy system) will invest a certain amount of energy in its productive process. It will also harvest a certain amount of energy. So, if this society is growing at even an insignificant rate, it must harvest more energy than it consumes in order to re-invest in the future.

Energy systems must, therefore, continuously tap readily available sources so as to produce the surplus they need. As the system grows and becomes more complex, so do the energy relationships that depend on the system (and the continued surplus). For this reason, the very specific conversion techniques found in various systems are ultimately contingent upon a multiplicity of factors. All of these factors lead to high levels of inertia and social control aimed at protecting the socio-political interests that are invested in the system. Simply put, once the many vested relations become dependent on the structure of an energy system, the ability and desire for change will obviously be limited by these same interests.

Using this idea, Debeir *et al.* (1991) elaborate upon the notion of energy systems so as to include the following definition:

> [a]n energy system is the original combination of diverse converter chains which draw on determined sources of energy and depend on each other, initiated or controlled by classes or social groups which develop and consolidate on the basis of this control (p.5)

In other words, the energy sources that feed a system are generally determined by two preconditions: (1) the technical knowledge that converts these sources in order to satisfy certain social needs and (2) these established social needs require that this conversion process (over given sources) guarantee access to a certain quality and quantity of energy (see ibid). These relationships are mutually reinforcing and, consequently, essentially "lock in" the use of specific energy sources (see ibid). Unfortunately, this mutually reinforcing relationship does not pay enough consideration to the energy source itself.

Clearly then, it seems that the relationship between the process of converting, or transforming, energy sources and the social structures that live off this transformation process, serve to shape human energy systems in very particular ways. This assumption, however, ignores the first fundamental reality of energy use: humans live in an organic community first and a social community second. It is therefore now necessary to elaborate upon an understanding of the biophysical laws concerning energy consumption.

D. Biophysical Realities: Thermodynamics and the Entropy Law

It is now necessary to further examine the biophysical nature of energy and, thus, the limits to energy use, with an examination of the principles of thermodynamics so as to better understand how the biophysical laws of the planet serve to shape the manner in which energy is transformed (see Daly, 1996; Georgescu-Roegen, 1993). These laws will then be examined according to the manner in which they shape the physical needs of any given energy community.

The First Law of Thermodynamics

When looking into the first and second laws of thermodynamics, as they apply to human energy systems, it also becomes clear that energy effects are far from neutral. Herman Daly (1996) draws attention to this by studying the first law of thermodynamics, which states that matter can neither be created nor destroyed. Dennis Pirages (1978) explains this further by stating that, the "amount of combined energy and matter in the universe remains the same, although the forms and usefulness of this matter and energy may change" (p.113).

From this point, Daly illustrates what he believes to be the biophysical foundations for establishing social and economic polices that incorporate the concept of *sustainable development* within modern energy-use paradigms. He does this through depicting the inimical relationship between the contemporary obsession with unlimited economic growth and the fundamental reality that human structures are simply an "open subsystem of a finite, non-growing, and materially closed ecosystem" (p.75). Therefore, through the most basic interpretation of the first law of thermodynamics, it is obvious that the consumption of any given energy source is limited by finitude. Standard economic thought, however, would argue that human beings have the boundless ability for discovering substitutes to resources (Daly and Cobb Jr., 1994). Nevertheless, when considering that energy system relations generally "lock-in" a preference for particular sources, and the conversion techniques that accompany these preferences, the ability to readily change entirely new substitutes is suspect at best (Debeir *et al.*, 1991).

It should also be understood technological capabilities can stretch the elasticity of energy sources to previously unimaginable lengths (IEA, 1991; IEA 1994). This, however, doesn't change the fact that matter and energy are still finite (see Ehrlich *et al.*, 1993). And, as Debeir *et al.* (1991) point out, the growing needs of an energy system will eventually outpace improvements made to conversion technique, and the availability of any given source, if alternatives are not actively sought out. In other words, the biospheric restrictions on energy use require recognition of absolute scarcity as opposed to relative scarcity (see Underwood and King, 1989).

The Second Law of Thermodynamics

Building on this, it is possible to evaluate the intrinsic correlations between energy system processes and natural energy process. To do this, the second law of thermodynamics - the law of entropy - must be examined (see Daly 1996). The second law of thermodynamics states that, in an isolated system, energy is essentially finite and naturally moves from a state of order to disorder; from a state of low entropy to a state of high entropy (see Georgescu-Roegen, 1993a). Simply put, the matter and energy found in an isolated system, as energy communities slowly consume it, will move from a state of unused energy to that of used energy. Entropy is, thus, the measurement of molecular disorder found amongst the energy sources within an isolated system, such as the planet earth (see Pirages, 1978).

Therefore, without the reintroduction of usable energy sources (low entropy), the biophysical system itself slowly moves toward higher rates of unusable energy (higher levels of entropy). Consequently, Nicholas Georgescu-Roegen (1993) argues that the law of entropy is the most significant restraint placed upon human activity. For instance, he shows that energy can only exist either as available free energy or unavailable bound energy. Free energy naturally implies an ordered organic structure where its molecular composition is unbound and can be readily used (see Pirages, 1978). In contrast, bound energy is dissipated and in disorder, where it exits in an unavailable state and can no longer be easily used, transformed, or consumed. A good example of this is found when looking at a certain quantity of gas that has been trapped inside a glass jar. When this gas is released into the atmosphere, "the densely packed molecules move toward randomness" (ibid, p.113). A more concrete illustration of this is the fossil fuels, and how they:

> represent highly ordered or less probable configurations of molecules with great potential to do work. This order is destroyed and the molecules move toward a more probable configuration while the work is being done. The molecules then exist in a more random,

> disorganized, and less useful form. Thus when fossil fuels are burned and work is done, the matter is degraded from more organized and potentially useful into disorganized and less useful forms. (ibid, p.113).

From this idea, Georgescu-Roegen (1986) moves to describe the difference between a terrestrial source (or stock) and a solar source (or flow). Terrestrial stocks are reservoirs for non-bonded low entropy energy. They remain in a state where energy is stored within them and, at the same time, remains in a highly ordered structure available for use. But then, when used, they cannot be used again. Take, for example, a lump of coal. Before being burned, it represents a highly ordered piece of matter with a great deal of potential energy stored inside (see Daly 1996). After it is burned, however, "this organization is destroyed, and the resulting heat, gases, and waste products have little capacity to do work" (Pirages, 1978, p.113). Entropy has, therefore, increased and the "dispersed products cannot be reconstituted into the lump of coal" (ibid, p.113).

A solar source, on the other hand, is not a reservoir of stored energy in and of itself, but is rather a flow of highly usable energy. It is called a flow because it simply flows from one larger energy system, namely the universe (or galaxy), into the smaller isolated system found on earth (see Daly 1996). This solar radiation is then captured in various ways and becomes the primary source of life on earth (see Debeir *et al.*, 1991). For example, solar flows stimulate chlorophyll photosynthesis. This, in turn, engenders and nourishes all of the single cell organisms found in the biosphere. Solar flows also control the temperature patterns on earth, which then create weather, an atmosphere, and the core temperatures within the planet that help to produce minerals, oils, and gases (see Manshard, 1998). In all this, solar flows are either directly or indirectly responsible for every energy source known to human beings. However, beyond the Agrarian pursuits of human beings, and the use of biomass fuels, solar flows have not been used as a primary source of energy for the purpose of maintaining any of our productive activities (see Mackenzie, 1992).

Now, re-considering that matter and energy cannot be created or destroyed, once a terrestrial source is used as energy (and converted into another form of matter), the entropy level within this energy system moves toward a higher state of disorder. According to Georgescu-Roegen, once the consumption of energy is greater than the regeneration of the sources, the level of entropy can only increase. This is a frightening thought, considering that all "industrialized countries are now living well beyond their natural 'solar income' carrying capacity" (Pirages, 1978, p.110).

The only way to lower this rate of increase is to use more of the available energy found in the solar flow. Georgescu-Roegen (1993a), thus, uses the laws of thermodynamics to critique modern conceptions surrounding energy use and economic logic in that humans (in the industrialized world) are almost completely reliant upon terrestrial stocks. This is a fact that he finds strange for two reasons: (1) the enjoyment of life - as defined by economic ambitions - requires ever increasing access to low entropy energy sources, so that a great deal of energy use potential can be maintained, and (2) terrestrial stocks contain only a small fraction of the free energy found in solar sources. This then begs the question, "why not use solar, or other renewable, sources?" To answer this, asking whether or not current energy systems require a change is now necessary. The next chapter will move us in this direction with a detailed assessment of fossil fuel sources.

E. Conclusion: Looking to Modern Energy Systems

It can, thus, be argued that modern understandings of social development and energy use are limited in their conceptual frameworks. Most notably, a proper understanding of environmental processes and alternative social goals are excluded from the popular, economically driven, notions of social development. Consequently, energy systems do not receive adequate consideration within contemporary development theories and practice.

Correcting for this, however, requires re-elaboration upon the basic characteristics of an energy system. Subsequently, it was shown above how energy systems, indisputably, are composed of both social and environmental processes. In this, it was also shown how a continuous flow of energy is essential to the survival of any given system. Unfortunately, as was demonstrated, these same systems generally become dependent upon a limited number of finite sources.

To further develop this idea, the notion of entropy was introduced so as to explain the dangers, both social and environmental, of relying upon limited and finite energy sources. In the end, the overuse of limited sources, such as terrestrial stocks, seems ill advised at best. Given this, the question that arises is "why would the modern industrialized world continue to overuse fossil fuels (a terrestrial stock)?" It now becomes possible to examine the modern fossil fuel based system, so as to elaborate upon the environmental and social problems that currently receive inadequate consideration within the dominant paradigm of global energy production. As such, its limitations will be better understood and the necessity of change will become more obvious, and - due to mounting cost - inevitable.

Chapter Three

"The Cost of Fossil Fuel Dependency"

A. Introduction

Before the mid point of the 19th century, global energy systems were fed almost entirely by renewable energy sources: "wood for heat and smelting; and water wheels, wind mills, sailing ships, and animal power for mechanical energy" (Mackenzie, 1992, p.16), not to mention human labour. But, during the past century and a half two major transitions occurred amongst the primary energy sources used by human beings (Schurr, 1960; Mackenzie, 1992). The first was a full-scale shift to the use of coal in the late 18th century. The second was the shift to the use of oil during the early 20th century (see Ayres, 2001). With these shifts also came the development the global fossil fuel infrastructure, which currently accounts for 80 percent (see IEA, 2001) of the global total primary energy supply (TPES).

With the shift to fossil fuel based energy production, human civilizations gained the ability to concentrate seemingly unlimited amounts of energy on any given task (see Pirages, 1978). Mechanical power no longer restricted the output of human or animal based power. Nor was it constrained by the limitations of wind and water. Rather, the fossil fuels allowed a new system of human production to evolve: large-scale industrial production (see Debeir *et al.*, 1991).

Today, industrial based energy systems, are found throughout the developed world. And, the current trend in development toward "globalization" will soon see industrial production emerging throughout the entire world. These systems, whether under democratic or non-democratic governmental structures, are universally "synonymous with complicated systems of production and distribution that require a constant injection of energy to keep them operating" (Pirages, 1978, p.110). As Dennis Pirages (1978) points out, even agricultural production in industrialized countries is dependent upon an enormous supply of fossil fuels. For example, modern farming techniques in the industrialized world require fertilizers and pesticides that are manufactured by fossil fuel based industries; mechanical equipment for planting, harvesting, and transporting products; storage facilities that are normally constructed by materials - such as aluminum, steel, and tar - which also require fossil fuel consumption during their fabrication.

Developed economies, and the centralized organizational structures that accompany these systems, are therefore "now part of the industrial way of life." However, it must also be recognized that this way of life is "very expensive in terms of energy consumption" (ibid, p.111). The vast array of consequences that result from the high energy "price tag," in the developed world, are both dangerous and uncertain (as will be elaborated upon shortly). Most notably, from a political standpoint, is that there is no alternative energy system that the industrial complex can turn to, should the fossil fuel system fail to provide a stable flow of suitable energy sources.

Building on this, it can now be argued that once the notion of an energy system, with both biophysical and social externalities being considered, is incorporated into the conceptual framework of fossil fuel use, this lack of an alternative suddenly appears even more precarious. For example, by looking to the dangers of fossil use in their entirety, and the threats that that these dangers pose to the system in general are understood, the need for an alternative becomes obvious. It is, therefore, upon this notion that the next chapter of this thesis will proceed by detailing the next step of the analytical framework illustrated previously; namely, discussing the consequences of fossil fuel use within the expanded parameters of an energy system study. As such, popular concepts of energy use, as is advanced within western thought, will not provide the basis for critical interpretations. Rather, three common and mutually reinforcing externalities will be examined, so as to conceptualize the full cost of fossil fuel use.

These externalities are: (1) the socio-structural costs, (2) the environmental costs, and (3) the security costs (in terms of both their social and biophysical characteristics). In addition, they will be further broken down and scrutinized within the context of each separate fossil fuel: coal, oil, and natural gas. There will also be a section that looks at these three externalities in relation to nuclear power – an energy source that must be considered within the larger context of the fossil fuel system because it stems from a finite mineral (uranium), is favorably subsidized, is highly centralized, and produces extensive environmental threats. This breakdown, in the end, will help to explicitly depict the many diverse side effects of fossil fuel use and the manner in which these side effects help to shape the modern energy system.

With this, a brief description of the current global energy system will first be presented so that contemporary energy consumption and production patterns can be better understood. Future projections will also be provided in order to help describe the "business-as-usual" scenario (as is espoused by modern analysts). It will then be demonstrated that, even though 21st century energy needs seem to require the further development of fossil fuels, a growing level of uncertainty pertaining to future energy related problems has, at the very least, initiated a belief in the necessity of an alternative.

The discussion of social cost will provide a quick look at the amount of public investment required to support the fossil fuel system. Most significantly, the current American energy plan, under the Bush administration, will be described in the way that it provides enormous amounts of financial support to fossil fuel industries. Other industrial countries will be looked at as well, but the US, as the worlds predominate energy consumer, will be focused upon. In this, there will be no question as to where structural loyalties lye when considering the idea of vested systemic interests.

Next, the multiple environmental costs of fossil fuel consumption will be examined. Consequently, the benefits and consequences of this system can be more accurately assessed. Put simply, by including this, the biophysical and entopic characteristics of an energy system will be give due consideration. Thus, the full transformative nature of fossil fuel use, as it relates to social development and environmental change, can be measured.

Finally, the idea of security threats to the energy system will be analyzed within the framework of vested social interests and environmental damage. As such, the threat of not developing an alternative, regarding the vast consequences that will arise from continued fossil fuel consumption, will be presented. With this, the framework for exploring alternative energy sources, like the renewables, will then be established. That being said, it is now time to look at the current global energy situation.

B. The Fossil Fuel Projections

By almost all accounts, fossil fuels are projected to remain the chief source of Total Primary Energy Production (TPEP) for at least the next thirty to forty years (see Lahidji, Michalski, and Stevens, 1999). They currently hold a 95 percent share in global commercial / industrial energy production and a 79.3 percent share of the global consumption of the TPES (see IEA, 2001). Furthermore, recent advancements in the exploration, research and production techniques of crude oils and coal products have greatly extended the possible uses of known reserves and, thereby, added to the life expectancy of all the fossil fuels. Newly discovered natural gas fields in Central Asia and Russia, along with attempts to start drilling in environmentally protected areas such as the Alaskan wildlife refuge (see IEA, 2000), have also added to the unwarranted optimism that fossil fuels will continue to be the principal driving force behind a sustained state of global economic growth (see Brown, 2001).

Unfortunately, according to the "business-as-usual" scenarios that are espoused by contemporary political and economic policy analysts, the overwhelming environmental consequences of hydrocarbon fuel utilization will be further intensified throughout the twenty-first century (see OECD, 1999). For instance, global energy consumption is expected to grow at a rate of 2.1 percent per annum through the year 2020, which translates into an increase of approximately 63 percent (see IEA, 2000). If this rate remains constant, the global consumption of TPES will be more than double its current level by the year 2040 (see ibid). During this time, the global Gross Domestic Product (GDP) is also expected to grow at an average rate of 2.8 percent per annum through 2020 (4.6 percent in the developing countries), thereby adding to the future marginal consumer power of the world's population base – a development that will only speed up the growth of energy demand (see OECD, 1999). When oil and gas production peaks, the subsequent increase in price will hurt those underdeveloped countries which have become reliant on these energy sources for their industrial infrastructure, and the temptation to turn to coal will be strong (see Pachauri, 1999).

After 2020, most energy projections become increasingly difficult and much more uncertain. This is due to the many doubts concerning the effects of changing demographics, environmental concerns, and political situations (see AI, 1997; Vouyoukas, 1996). For instance, even though prolonged economic growth might decrease rather than increase, demands for fossil fuels, particularly if an overall increase in the general affluence of global populations occurs, "could well lead to higher demands for environmental quality" (Lahidjii, *et al.*, 1999:19). Nevertheless, one assumption remains constant throughout the various projections: energy systems will remain predominately based upon non-renewable resources - mostly the fossil fuels with nuclear power playing a small, but potentially increasing, role - until the late 21st century (see EIA, 2001). Renewable resources are therefore not expected to gain a significant market share until the mid to late part of the century; but the necessity of tackling many unforeseen problems might inspire a faster transition (see

Flavin and Dunn, 1999). So, at this time, it now necessary to detail the manner in which these unforeseen problems will likely arise within the fossil fuel system.

C. Coal

Coal is the most abundant of the fossil fuels with "by far the largest resource base", and its' "widespread geographic distribution, low cost and price stability" (IEA, 1997, p.53) guarantee that it will play a very important role throughout the globe (as a fuel source) in the production of energy (see EIA, 2001). Due to the specific geological conditions that create it, coalfields are found in well-defined but abundant areas. Most of these fields are "composed of seams found at varying depths and widths, indicating repeated plant growth, water coverage, and burial of matter beneath the waters" (Pirages, 1978, p.114). In this, coal (as with the other fossil fuels) is unlike the other non-fuel minerals in that it represents a stored solar income. Coal is therefore a finite energy source that is ultimately limited by the rate in which the planet's biophysical process can recreate it.

Nevertheless, at current consumption rates, the known coal reserves across the plant are enough for more than two centuries of use (see Lawson, 1995). In addition, with the ever-increasing ability to stretch the efficiency rates of coal use, this time period could be stretched to a seemingly limitless amount (see IEA, 1997a). For example, recent thermo efficiency rates, in the new coal-based power plants, have been increased by more than 50 percent (see IEA, 1996a). In some cases, these rates have been enhanced by as much as a factor of ten (see IEA, 1995). When looking to these projections, there is little doubt that coal, as an energy source, can be maintained for many years into the future.

Coal was the first of the fossil fuels that was used by industrial countries for large-scale energy production (see Ayers, 2001). Initially, it served as a replacement for wood to meet heating needs and in the smelting of iron throughout England. In fact, when faced with a severe shortage of wood, the "entire [English] iron industry was saved by the substitution of coke (made from coal) for charcoal" (Mackenzie, 1992, p.20). Similarly, 75 percent of the heating needs for the United States were met by coal (see ibid) in 1900. Coal slowly became the primary energy source for American industry and transportation while wood grew both more scarce and expensive. By the turn of the century, coal production had grown by as much as 60 percent from its rates in 1850 so as to account for "80 percent of [American] total fuel needs" (Mackenzie, 1992, p.21).

Currently, coal holds a 22.2 percent (84.8 Quadrillion BTUs)[1] share of the global TPES (see EIA, 2001). And, according to recent projections, it will soon enjoy an increasing share of this percentage as oil and gas production begins to level off over the next 20 years. When compared to the projected rise in global energy consumption, this constant share of global TPES will translate into an actual increase of output that will reach 134.5 Quadrillion BTUs (see ibid). In particular, coal is projected to occupy an ever-increasing position within the production and security of energy supplies in key economies of the developing world (see Pachauri, 1999). Akira Kinoshite (1995) argues that "coal dependency" in the developing countries

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[1] One aspect of the difficulty involved in energy comparisons and analysis is the myriad of measurements used. For our purposes, when looking at fossil fuel and nuclear energy consumption, we will be referring to British Thermal Units (BTU). To better understand how this measurement compares to others please note the following: 1 BTU = 1055.056 Joules (energy): 1 Watt (power) = 1 Joule (energy) per second (time).

will exceed 60 percent until near 2050; nearly three-quarters of energy production in China will be generated by coal until 2010.

Social Cost

For well over 100 years now, coal has been a primary energy consideration for government and industry leaders. During this time a very large and powerful infrastructure, and a subsequent infrastructural bias toward coal use, has also developed; this bias now serves to favor coal's continued use throughout the world. For example, the experience, relative stability, and global distribution of coal markets - along with the abundance of coal itself - significantly contribute to its predominance within international energy production (see IEA, 1995). It is important to remember, however, that these market and infrastructural systems were only accomplished through extensive governmental support, which favored "large-scale" centralized energy production (see Dunn, 2000a); the "bigger-is-better" dogma that has only recently come under serious criticism. The infrastructural foundation for the coal industry was therefore built through subsidies, tax incentives, natural resource regulations, and publically funded transport systems.

Today, these biases continue to evolve and shape the energy systems of industrial countries around the world. Nowhere is this better illustrated than is found with the Bush administration in Washington and their need to pass the energy bill H.R.4 (see GSC, 2002). Under this bill, the coal industry will directly receive 2 billion dollars (over 10 years) in order to encourage the development of clean coal technologies (see ibid). It will also receive indirect support through "a precedent-setting production tax credit" (FOE, 2001, p.2), which would allow utility companies who burn coal "to take credit for every unit of energy produced" (ibid, p.2). Finally, existing programs dedicated to developing technologies that improve the thermo efficiency of coal will be expanded through further subsidization and tax incentives (see GSC, 2002).

In total, H.R.4 will hand out over 5.8 billion dollars to the coal industry (see ibid). But, whether or not these incentives will be of great benefit to the average American energy consumer remain up for debate (see Cassady, 2000). The American General Accounting Office (GAO), the US government's fiscal watchdog agency, points to this by reporting that, despite the US Department of Energy's reports detailing the success of clean coal technologies,

> Over the years we identified numerous management weaknesses in the program. In particular, we reported that multiple clean coal technology demonstration projects experienced problems and difficulties in meeting cost, schedule, and performance goals. As we reported last year, of 13 projects we examined, 8 had serious delays or financial problems - 6 were behind their original schedules by 2 to 7 years, and 2 projects were bankrupt and will not be completed. (Wells, 2001, p.4)

In this report, and seven others, the GAO details that the US Clean Coal Technology Program (CCTP) has a history of "egregious waste, mismanagement and failure in the use of CCTP funds" (FOE, 2001, p.2).

In terms of the other subsidies and tax incentives offered to the coal industry, the Joint Committee on Taxation (JCT) maintains that these tax subsides will come at a direct cost of 3.3 billion dollars to the American tax payer (see JCT, 2002). Consequently, the watchdog group U.S. Public Interest Research Group (US PIRG) argues that such costs leave the average taxpayer to pay for a dirty and dangerous energy system, while energy industries benefit in an ever-increasing manner (see FOE, 2001). In fact, for the 3.9 million dollars that was donated as gifts and contributions to congress from 1993 to 1999 by companies involved in the CCTP, 787 million dollars in subsidies was handed back out; this represents a 202:1 return on investment for these companies. And, with the Bush Energy Plan, this return can only further increase (see Cassady, 2001).

Environmental Costs

Interestingly, the desired effects of clean coal technologies can just as easily be accomplished by clean air regulations, such as those found in the 1990 amendments to the American Clean Air Act (see US EPA, 2002). Such regulatory measures can force the industry to remove many of the dangerous elements from coal if it is to remain cost competitive (see CA, 2001). Nevertheless, these regulations are also now under attack from the Bush administration, as they have recently called for the US clean air standards to be relaxed in the interest of economic security (see Connole, 2001).

The dangers of such a move, nonetheless, extend far beyond the concept economic well-being. Even though coal is seen as such a major element of long term energy production, it must be remembered that it also presents much larger environmental risks than even the other fossil fuels (see CA, 2001). It contains elements such as Sulfur Dioxide, Nitric Oxide and Nitrogen Dioxide, Carbon Monoxide, Carbon Dioxide, various particulates and other heavy metals, which are all released into the atmosphere during the combustion process (see ibid). This release contributes directly to problems such as increasing green house gases (GHGs) in the atmosphere, the depletion of stratospheric ozone, the acidification of natural environments, and an increase in the levels of smog and air pollution (see Graedel and Crutzen, 1990). It also contains the highest levels of carbon per calorific value of all the fossil fuels and therefore releases the highest levels of Carbon Dioxide (the most predominate and effective anthropogenic GHG) during the fuel cycle process (see IEA, 1996a).

Coal fired power plants in the US account for one third of the nation's nitrogen oxide (NOx) emissions, two thirds of the sulfur dioxide (SO2) emissions, and one third of mercury emissions (see CA, 2001). These plants also emit toxic metals such as beryllium and nickel and toxic gases such as hydrochloric acid and hydrogen fluoride. The SO2 and NOx emissions are usually fine particulates that can travel thousands of miles and affect people almost anywhere (see Myers and Kent, 2001). In addition, the NOx also increases ground level ozone, which is also known as smog. Coal fired power plants actually emit more than 60 different toxic chemicals into the natural environment - more than any other industry (see GSC, 2002).

As a result, over 140 million people across the US live in areas of the country with air pollution levels above federal safety standards, over 600 thousand people suffer from asthma, and over 60 thousand people die prematurely because of respiratory related problems (see Myers and Kent, 2001). Coal dust kills some 2000 U.S. miners every year (see Jacobson and Masters, 2001). Furthermore, the toxins that subsequently end up in the natural environment destroy aquatic habitats and contaminate drinking water sources. Emissions such as mercury, cadmium and lead, therefore, enter the food chain and contribute to developmental problems in children and immune system damage in both children and adults (see CA, 2001).

The burning of coal is not the only time when environmental damage occurs. The recovery and transportation of coal is a very fuel intensive procedure. Mining is a procedure that dramatically alters the landscape and renders vast tracts of land useless for decades to come. It also requires huge machines that, themselves, are powered by fossil fuels. Not to mention the contamination of land and water supplies that is inevitable when resources are extracted in bulk from the earth's core.

If that were not enough, once the coal is removed, cleaned and made ready to ship, all the left over waste produced in the cleaning process must be transported and stored as well, which creates the risk of spillage and environmental contamination (see Vendetti, 2001). This is evidence in a recent spill in Eastern Kentucky, which curiously received little attention from the media. For example, an article in the Ecologist (2002), submitted by an anonymous author, states that:

> One of the largest, if not the largest, environmental disasters in the history of North America occurred deep within the Appalachian Mountains of Eastern Kentucky (US) last October. A coal waste impoundment, owned and operated by Martin County Coal Co (owned by A T Massey Coal Co; owned by the Flour Corporation) broke into abandoned underground mines and spilled in excess of 750 million gallons of coal slurry into nearby streams and rivers. Even though it was many times greater than the infamous Exxon Valdez disaster, and directly affected many towns and villages, the mainstream media, national environmental organisations, and political entities paid little or no attention. (p.12)

Finally, the high levels of carbon dioxide found in coal will inevitably become of greater concern for National governments, policy makers and an increasingly environmentally-aware public. However, given the apparent strategic necessity of and dependence on coal consumption for energy supply security, especially in highly populated developing countries like India and China (see

Pachauri. 1999: Lawson. 1995), it seems that both politically and environmentally acceptable solutions will become more and more difficult to reach. International cooperation in the areas of Research and Development (R&D). Technology Transfers and Environmental Regulations must therefore be a major contributing factor to the future production and consumption of coal if the impending ecological problems associated with fossil fuels are to be adequately dealt with (see IEA, 1994; IEA, 1996).

Security Concerns

The most obvious challenges concerning coal use, especially in developing countries, would be the increased levels of air pollution in areas that already face dangerous levels of air quality, land loss from mining practices, and the multiple effects of climate change. Subsequently, traditional security threats, such as the threat of attack from a foreign nation aimed at destroying or capturing an energy supply, are not an overly immediate concern when considering coal. The reason for this is the immense distribution of this fuel source around the globe (see Pirages, 1978). Simply put, everyone has access to coal reserves. Ironically, however, it is this vast distribution that actually creates the security threat of coal usage - dependency on coal leads to multiple environmental problems (as was mentioned), which then create economic and social problems for any given nation (see Myers and Kent, 2001).

The security threat of coal use can, thus, be seen on two fronts: (1) dependency and (2) environmental instability, both of which seem inevitable given the current energy system. As R.K. Pachauri (1999) argues, even though global interest in sustainable development requires a reduction in carbon dioxide emissions, as well other air and land pollutants, it is not feasible to ask countries like India and China to stop using coal in their energy production systems. These countries are currently dependent on their large domestic coal reserves for developing an energy production infrastructure (see Lawson, 1995), which is believed essential to economic health in an industrial world.

From this, Pachauri challenges the ethical assumption that the developing world is responsible for reducing coal emissions since many industrialized nations "produce and use much higher quantities of coal in per capita terms than their developing counterparts" (p.104). Nonetheless, he recognizes that the environmental consequences of coal use are a very immediate concern and have not gone unrecognized. For example, Pachauri points out that the government of India has worked to establish an extensive environmental protection and emission control apparatus. However, this same apparatus is creating sever conflicts between industry and the government because of the fact that many national companies cannot afford to implement the required changes. To make matter worse, Trans National Companies (TNCs) simply take advantage of the relaxed resources exportation regulations of the global market, and build their plants in countries with more relaxed environmental restrictions (see Cobb Jr., 1995). India is, thus, left with little choice other than using their coal reserves for industrial production.

Unfortunately, the majority of coal found in India and China (as is with most developing countries) is of a grade much below that found in most western world countries (see Pachauri, 1999). They do not have access to the clean coal technologies employed by the west, which means that the environmental consequences are compounded even further. And, when considering that the so-called clean coal technologies used in the west, themselves, produce vast environment and anthropogenic problems, the prospects for the developing world seem despairing.

To put this threat in its proper perspective, taking a more in depth look at the consequences of coal use will now be helpful. For example, when looking to acid rain, the health benefits of controlling it in the United States costs between 12-40 billion dollars per year; in Europe, the commercial losses in timber amounts to 30 billion dollars a year; in China, the loss to tropical forests cost 14 billion dollars per year (see Myers and Kent, 2001). Air pollution has been tied to annual loss in agricultural production that equals 4.7 billion dollars in Germany, 2.7 billion dollars in Poland, 1.8 billion dollars in Italy, and 1.5 billion dollars in Sweden. Fine airborne particulates have been linked to almost 500 thousand avoidable deaths every year. Given the current business as usual scenario, this number is expected to climb as high as 8 million people if energy production patterns are not changed (see ibid). For countries such as China, this will translate into a rise in health care costs from 32 billion dollars in 1995 to almost 1 trillion dollars in 2020.

All of these figures are only a tiny sample of what the human, economic, and environmental costs of coal production are (see ibid). Most significantly, these figures make no mention of what the potential results of global warming will, where even the most conservative estimates peg the economic damages at 1 trillion dollars a year (see IPCC, 2001). Clearly then, it is not possible to consider continued a coal use a threat to economic and environmental security - a problem that is compounded by its abundance and subsequent necessity throughout the world.

D. Oil

Oil and natural gas are formed much in the same way as coal when land and water slowly cover organic remains so as eventually create a decay and transformation effect under the plants geological pressure. They are, however, are much more scarce than coal - found in very specific areas called pools, which seldom exceed a geographic size larger than 100 square miles (see Pirages, 1978). The reason for their relative scarcity, in comparison to coal, is the increased complexity involved in their creation. For example, "petroleum and natural gas are produced [when] compacting shale squeezes organic matter into liquid and gas hydrocarbons, rather than into coal" (ibid, p.114).

Interestingly, these gases and liquids are not found in the same place in which they are formed because they are pushed from high-pressure areas to low-pressure areas in an upward motion toward the surface of the planet, where they eventually reach a 'geological trap' (see ibid). This trap is an impermeable rock formation, which halts the upward motion and thereby contains these fuel sources. The combination between the rarity of suitable geological formations that can produce this trapping affect, and the complexity involved in the creation of liquid and gas hydrocarbon fuels, explains the limited number of places on the planet that can produce petroleum and gas (see ibid).

Consequently, the more that these fuel sources are consumed by human energy systems, the more difficult it becomes to find new geological areas with adequate reserves. Simply put, as the 'traps' closer to the surface are emptied, it then becomes necessary to drill into deeper and more complex areas of the earth's core. With this, the process becomes more and more expensive – it is essentially an inflationary process (see Commoner, 1979). Nevertheless, major oil companies are currently sitting on "hoards" of cash. As is reported by the *Wall Street Journal* "the [oil] industry is sitting on nearly $40 billion in cash, and the figure is likely to balloon in coming months" (quoted in FOE, 2001, p.1). Obviously then, an ever increasing expense in oil recovery poses little threat companies with such large "bank roles".

In a recent "Energy Survey" published by *The Economist* (2001), Lee Raymond, the Chairman of Exxon Mobile, said that his company intends to spend over $10 billion U.S. on proprietary technology and investments, and that "not a penny of that will go on renewable energy" (p.7). The oil industry can afford to devote such funding because it has confidence in the immediate future. Put simply, the combustion and consumption of crude oil is used in such a wide variety of human activities that it is currently the single most important fuel source on the planet and fundamentally provides us with the energy foundation of our global economy. It is used to produce refined fuels for things such as transportation, power generation, heating, cooking and industrial production. It is also used for the development of all petroleum-based products, such as rubber, plastics and petroleum- based jellies and lubricants.

The oil industry, like coal, has a very extensive and politically powerful global infrastructure with a highly evolved and heavily interdependent international market. It also enjoys exceptionally developed R&D networks that extend throughout the financial, scientific, and political communities (see OECD, 1999). In addition, the oil industry enjoys an overwhelming share of current global energy markets and is favored to be the most important energy source for the majority of the upcoming century (see EIA, 2001; OECD, 1999). Presently, approximately 77 million barrels of oil are produced every day, which is expected to rise as high as 113 million barrels a day by 2020 (a 54.7 percent increase) (see IEA, 2001). This large increase in production, however, translates into a slight projected decrease in oil's share of TPES consumption from 39.9 percent (152.2 Quadrillion BTUs) in 1999 to 37.9 percent (230.4 Quadrillion BTUs) by 2020 (see EIA, 2001).

Social Cost

Just as is with the coal industry, "Big Oil" receives extensive tax, subsidy, and social infrastructural support from every industrialized nation. Proof of this is ample and indisputable. To see this, one need look no further than pipeline development, land leases for drilling companies, road and transportation developments, fuel efficiency standards, fossil fuel tax incentives, relaxed environmental regulations, and governmental R&D programs. In fact, the popular rhetoric found with western nations simply acknowledges that oil is an essential element to economic stability and national security.

The United States and Canada have made few, if any, specific efforts to reduce oil production and consumption (see Canada, 2000; EIA, 2001). In fact, both of these countries are currently pursuing energy policies that will increase their respective national dependency upon oil. Given this, once again addressing the Bush Energy Plan, along with North American oil consumption and production patterns, will help to further examine the social investment within the oil industry (see GSC, 2002). For example, the current energy bill (H.R.4) in Washington demonstrates these investments very well. Under H.R.4 the oil and gas industry will receive more than 21 billion dollars in tax relief and subsidies (see ibid). In particular, this bill creates over 14 billion dollars in tax loopholes, establishes R&D programs, and allows companies to take exemptions from paying royalties. In particular, R&D programs will be developed to aid oil companies who are involved in 'ultra deep-water' drilling, so as significantly reduce the tax and royalty requirements these companies need to pay (see Cassady, 2001). These programs will receive 900 million dollars over 8 years and an estimated addition 3 billion, which will be generated through federal oil leases (see FOE, 2001). H.R.4 will also give large tax deductions to 'marginal well owners' so that they could deduct more than 65 percent of total revenues and over 100 percent of total profits (see ibid).

In Canada, by comparison, crude oil and petroleum production is, and has been, an enormous aspect of domestic and international energy activities throughout the second half of the twentieth century (see Canada, 2000). Moreover, both consumption and export rates continually increase at a steady rate (see ibid). Recent exploration and development projects located in previously presumed unrecoverable areas, such as the Alberta oil sands and off-shore platform drilling, have served to further indicate the extensive Canadian commitment to the oil industry (see Canada, 1997a). In addition, the policy dictates of Canadian international activities have given priority to the oil and gas sector since the oil crisis of the 1970's and 80's.

And, even though agencies such as the Canadian International Development Agency (CIDA), Natural Resources Canada (NRCan), and the Canadian Department of Foreign Affairs and International Trade (DFAIT) all claim to be governed by the notion of sustainable development (see Canada, 1997), a strong institutional bias still supports the infrastructural expansion of the oil enterprises (see Canada, 2000). On top of all this, "green" technology funds initiated by the government have also contributed to developing energy efficient technologies that enhance exploration, recovery, processing, and pipeline construction techniques (see Canada, 1997a; CIDA 1998). All of which, ultimately help to maintain a global state of oil "over-development".

Environmental Costs

Oil exploration is itself a form of environmental stress, and the oil industry has been known for wastefulness. For example, until recently as much as two-thirds of targeted oil deposits were left unrecovered once a drilling was abandoned, because the geological structure of the site and the limitations to drilling techniques made it impossible to retrieve larger amounts (see OECD, 1999). Losses of oil at the site in the form of waste would also reduce amounts recovered, not to mention contribute to greater environmental degradation. Imboden and Jaeger (1999) claim that approximately "0.08 percent of annual crude oil is lost to the environment, mainly to water. This amounts to 3 million tons per year, equal to the total lost in all major tanker accidents to now" (p.74). An average of 180,000 gallons of waste mud is generated by drilling wells ever year. Most of this mud contains toxic metals, such as lead, mercury and cadmium, and is simply dumped untreated into nearby waters (see OECD. 1999). Produced water. which is water that comes up in a platform well along with the oil and gas, is another dangerous externality of oil drilling. This water is generally very toxic and contains pollutants such as benzene, lead, zinc, arsenic, naphthalene. toluene. and even certain amounts of radioactive substances (see NET, 2001). The US Minerals Management Service estimates that every single oil platform discharges hundreds of thousands of gallons of produced water every year (see ibid).

Oil spills are another major source of environment stress. When oil is spilled into the natural environmental it becomes an extremely toxic substance that endangers a vast array of marine life, bird life, and animal life. In addition, water supplies, food chains, and entire ecosystems can be placed in jeopardy (see NRCD, 2001b). Human commercial interests that depended on fisheries, tourism, and coastal recreation are also damaged when oil spills occur. And, despite industry claims, improvements in technology have not minimized these risks. For example, if we were to simply forget about the ever-present threat of oil tankers being involved in some sort of accident, oil platforms, wells, and pipelines also provide a constant environmental hazard (see NET, 2001). The US Department of the Interior reports that 3 million gallons of oil have been spilled in Outer Continental Shelf (OCS) drilling operations in 73 occasions over the past 20 years (see NRDC, 2001b). One such incident occurred in April 2001 when 90,000 gallons of oil and saltwater spilled out in Alaska's North Slope, which was the forth major spill in three years (see ibid).

In addition to the threat of oil spills, drilling is a very fuel intensive process that burns a great deal of fuel and, thus, contributes to air pollution. According to the Natural Resource Defense Council (2001b), an average exploration oil well will generate approximately 50 tons of nitrogen oxide, 6 tons of sulfur dioxide, 13 tons of carbon monoxide, and 5 tons of volatile organic hydrocarbons[2]. Platforms, in comparison, produce approximately the same amount of air pollution, except they will generate almost 40 tons of volatile organic hydrocarbons (see ibid).

All of this does not even take into consideration the enormous amounts of air pollution produced from within the transportation sectors of society. No better example of this can be found in the 8 million barrels of oil consumed each day by cars and trucks in the United States (see Sierra Club, 2001), which accounts for 40 percent of the oil used in their national energy system and 20 percent of their carbon emissions. Interestingly, raising the Corporate Average Fuel Economy Standard (CAFE) to an average of 40 miles per gallon over the next 10 years would save 3 million barrels of oil every day (see ibid). This saving would amount to more oil than all of the current Persian Gulf imports, the production of offshore drilling operations in California, and the reserves found in the Artic National Wildlife Refuge combined (see ibid). But, sadly, not only are the current Bush Administration and the

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[2] "Volatile Organic Compounds or VOCs are organic chemicals that easily vaporize at room temperature. They are called organic because they contain the element carbon in their molecular structures. VOCs have no colour, smell, or taste. VOCs include a very wide range of individual substances, such as hydrocarbons (for example benzene and toluene), halocarbons and oxygenates. Some VOCs are quite harmful, including benzene, polycyclic aromatic hydrocarbons (PAHs) and 1,3 butadiene. Benzene may increase susceptibility to leukaemia, if exposure is maintained over a period of time." (EAE, 2000)

Republican congress against raising CAFE standards, they also support lowering the air quality emission standards (see Connole, 2001; Sierra Club, 2001).

Security Concerns

The security of supply, as national leaders often refer to, is much more of a threat when considering that oil (as opposed to coal) is a geographically limited fuel source (see Yergin, 1991: Pirages, 1978). This security threat is made even more relevant when one considers the overwhelming amount of oil consumed on a daily basis throughout the industrialized world (see EIA, 2001)[3]. In the United States this problem is particularly significant. It consumes "25 percent of the world's total oil, but has only 3.4 percent of proven reserves" (Mackenzie, 1992, p.29). In fact, the U.S. consumption rate for oil is over 18 million barrels a day, which is an amount that is more than the yearly consumption rate of Europe, Africa, or the former Soviet Union (see ibid).

In this American consumption, less than half of it is produced domestically - about 8 million barrels a day. And, the U.S. Geological Survey (USGS) only 0.4 percent of recoverable American reserves are currently located within the protected lands of the Rocky Mountains (see NET, 2001). More significantly, the amount of oil found in the Artic National Wildlife Refuge (ANWR), which is under much debate at the moment, at best contains 16 billion barrels of oil (see ibid). Of this, it is estimated that approximately 3 billion barrels are 'economically recoverable', which is only equal to a six-month supply for current American needs (see ibid). In addition, it is

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[3] According to OECD statistics, this amount is 73,215 thousand barrels daily. (see NEF, 2002)

also believed that, if open for drilling today, it would take 10 years before the oil in the ANWR was ready for consumption in the American market (see ibid).

That being said, it is argued that new advancements and next-generation technologies in data evaluation, drill engineering and retrieval techniques will enhance the industry's ability to obtain larger amounts of current reserves and reach previously believed "unreachable" oil (see IEA, 1996a; see IEA 1997). In addition, new and improved data collection and exploration technologies will allow for faster and better discoveries of new reserves (see OECD, 1999). In Europe the oil supply problem is not as serious as it is in the US. European nations, who have traditionally lived under much greater limitations concerning their energy consumption patterns than found in North America (see Nye, 1999), are currently making much greater attempts the diversify their energy mix. Oil is still a major component of energy consumption pattern in Europe but, according to projections, will play an ever-decreasing role (see EIA, 2001).

However, in other places in the world, such as Asia, oil supply issues will soon be crucial element of geopolitical policies and international security. As Fesharaki Fereidun (1999) points out, the previously interventionist countries throughout the Asian-Pacific are now liberalizing their markets and facing a growing energy crisis, which stems from the misallocation of limited domestic reserves. Accordingly, Fesharaki (1999) argues that oil must play an expanded role in the continued development of these countries. Therefore, he maintains that it is necessary to increase trade with the Middle East, the Atlantic Basin, and Central Asia. The apparent necessity for this stems from the fact that oil imports into the Asian-

Pacific are expected to double in the next 10 years (see EIA, 2001). This will, of course, lead to several problems, such as increased conflict over scarce resources, transportation congestion on the seas, and further environmental damage.

In all this, the issue of supply insecurity continues to be an issue of concern for national governments throughout the world. Nevertheless, just as is with coal, the perceived dependency on oil serves to make the very consumption of oil a security problem. And, when considering the vast social investment in the oil industry, the obvious question that arises is "cannot national security be better addressed if this money were to be spent in securing a viable alternative – especially when oil industry profits are also considered?" This question becomes even more pertinent when the vast environmental consequences are placed within the equation. Finally, it is inevitable that the ultimate limits of oil reserves will be reached. As energy consumption patterns grow, these limits will only be reached sooner (see Flavin and Lenssen, 1994).

E. Natural Gas

Natural Gas is the most "environmentally friendly" of the fossil fuels. It is primarily composed of methane gas, which is a GHG, but one which burns cleaner and has fewer environmental side-effects than carbon dioxide (see Gibbons *et al*, 1990). Methane is also a gas that contributes to ozone depletion but at rates that are much less significant than its more insidious counterparts, such as CFCs. The somewhat more benign nature of methane, combined with improving technologies throughout the oil and gas industries, help to place an ever increasing emphasis upon natural gas as an alternative to both coal and oil production (see IEA, 1997). For example, recent advancements to surface exploration and recovery techniques not only allow for the discovery of new reserves, but they also increase the availability of natural gas found at abandoned oil drilling sites. Gas recovery can be fused with other technologies, such as clean coal and biomass gasification techniques, which require sequestering carbon dioxide in the ground (see IEA, 1994). For instance, the removed carbon dioxide can be stored in areas where natural gas is located, thereby displacing the methane, making the latter available for recovery (see Canada, 2000). It is for these reasons that natural gas is projected to maintain an increasing share of global energy use well into the twenty-first century.

In 1999 the use of natural gas accounted for 22.75 percent (86.9 Quadrillion BTUs) of the global TPES consumption, which is projected to be 28.51 percent by 2020 (173.3 Quadrillion BTUs). This will translate into a total increase of natural gas supplies by 106 percent (see EIA, 2001). Due to the fact that natural gas is 1000 times more voluminous than petroleum in its organic state, its transportation is the principal concern for its' industry. Accordingly, most of the R&D directed toward this energy source has been focused upon shipping techniques, especially because of the benefits of technology "cross over" from the petroleum industry, which already ensure improvement to technologically oriented areas such as exploration and recovery (see IEA, 1997). One important focal point has been conversion techniques, which make it easier to transport. For example, research has been done on converting methane to a liquid gas (which needs to transported at a temperature of -162°c), compressed gas (which needs to be kept in high pressure tanks), or the direct conversion of methane to electricity through the use of turbine generators (which can achieve thermal efficiency rates up to 60 percent but, nonetheless, will lose some energy during the transportation of this electricity) (see ibid). Other possible applications include alternative techniques such as the creation of hydrogen to be used in fuel cells (see Joyce, 2000). In terms of basic transportation techniques (the use of pipelines), the current infrastructure throughout the industrialized world is enormous and highly developed. However, the consumers of end-use products (electricity, transportation fuels, space heating and cooking) reside large distances away from reserve supplies, which obviously complicates the situation (see OECD, 1999).

Social Cost

Much of the social investment in the Natural Gas industry has been done through the oil industry (see IEA, 1995a). But, as the end of the oil era approaches, the production of this fuel source will become increasingly important. Countries like Canada - who enjoy large natural reserves - will soon become major gas traders (see Canada, 1997a). For example, in Canada, consumption and trade in natural gas is continuing to grow (see Canada, 2000). It is currently the world's second largest exporter and third largest producer. The industry is also playing an increasingly important role in the Canadian economy as a domestic and international energy supplier. Furthermore, as global energy markets shift toward greater production and consumption of natural gas, resource-based geopolitical concerns will inevitably lead to more emphasis on Canada - especially given the recent American obsession with energy supplies (see IEA, 1995a).

This shift, of course, has more to due with the deregulation of international markets, technological enhancements, and cost reductions than the ecological solutions apparently provided; Solutions that seem less environmentally benign when considering the entire fuel cycle, which consists of energy intensive activities like exploration, drilling, processing and fuel transportation (see Net, 2001). Nevertheless, as a member of the oil and petroleum family, natural gas maintains a relatively preferential position within global energy projections (see EIA, 2001), especially when considering the emerging needs of global emission reductions and energy efficient technologies (see IEA, 2000).

That being said, current concern over natural gas prices is assumed to be a barrier to getting this fuel source into the market (see IEA, 1997). This is a claim, as is with most market based analysis, that rests upon the assumption that current production levels are too low and further investment on the supply side is therefore necessary (see IEA, 1997a). By doing this, a market of scale will be created, prices will be regulated by the free market mechanisms, and energy security will be maintained (see IEA, 1995a). This argument, however, first fails to consider that creating an emerging market of scale for natural gas would require a great deal of social investment in the form of pipeline and transportation support, land leases, and research and development programs. For example, according to a recent article in the *Oil and Gas Journal* (2002a), submitted by an anonymous author, states that:

> [US] Senate majority leader Tom Daschle (D-SD) wants to direct North Slope producers and pipeline companies to build an arctic gas line paralleling the oil pipeline and then the Alaska Highway to British Columbia. He also favors a guaranteed natural gas floor price for producers to make the pipeline project more attractive to industry when market prices are low. (p.7)

Accordingly, it is the projected demand in North America for natural gas that has spurred the apparent need for new pipeline projects that will be built from Alaska, or northern Canada, down into the United States. One such project can be seen in what is known as the Mackenzie Delta project that would see a major pipeline built in Canada's Northwest Territories in order to tap reserves found along the Beaufort Sea. This would be a joint project that involves aboriginal groups, a group of major oil companies, and both the federal and various provincial governments (see Editorial, 2002). At this point, the project is in the planning and regulatory stage, which will take approximately four more years and cost 250 million Canadian dollars. And, in total, preliminary costs estimates "concluded an 'over-the- top' project would cost about $15 billion (U.S.), $2 billion less than the Alaska Highway route" (ibid, p.19). Clearly, investments this large help to ensure that natural gas will play a growing role in meeting future energy needs - even if further development is damaging on many social and environmental fronts.

Environmental Cost

As was mentioned, Natural Gas is the cleanest of all the fossil fuels and, as such, must be considered an integral element of the future energy needs around the planet (see IEA, 1995a). The problem with this, as was mentioned, is that increases to production and demand will therefore require further investment in pipelines and carrier technologies (see IEA, 1997). These are extremely capital intensive and inflexible once in place, and raise questions about local ecosystem disturbances during construction (see NET, 2001). Maintaining the structural integrity of pipelines then becomes an issue of concern as well. For instance, as a pipeline ages the threat of damage increases and, thus, so does the possibility of leaking gases into the atmosphere (see ibid).

Further development of new pipelines would, thus, not only increase the risk of environmental damage caused by leakage problems, it would also dramatically affect vast tracts of the natural environment. For example, pipelines in the Gulf of Mexico are estimated to be responsible for the destruction of more coastal wetlands than are located between the states of New Jersey and Maine (see NRDC, 2001b). Accordingly, opening up drilling and building pipelines in the ANWR would require hundreds of miles of roads, thousands of miles pipelines, millions of cubic yards of gravel, water to displaced from regional lakes, rives, and ponds (see NET, 2001). It would also require the constructions of ports, power plants, airfields, processing plants, landfills, and human infrastructures for the workers who move into the area - all of which carry an environmental 'price tag' of their own (see US Fish & Wildlife Service, 2001). Current oil and gas activities within Alaska's North Slope region clearly support this argument. As an illustration, in the Pruhoe Bay region of the North Slope, where oil and gas production is taking place, dozens of contaminated sites and waste pits have yet to be cleaned up, spills occur on a regular basis, thousands of tons of air pollution are dumped into the air every year, tens of thousands of acres of land has been covered by oil facilities, and over 800 square miles of land has been used by the oil industrial complex (see NET, 2001).

In this, opening up the ANWR provides an excellent example of how oil and gas operations produce direct environmental side effects because of its currently 'untouched' status. For instance, the Porcupine caribou herds, who reside in the

ANWR, depend on the same area of land as has been proposed for drilling. This is the only area in the entire refuge, a thin strip of land of 20 to 40 miles in width, that the caribou can use for their yearly calving requirements (see US Fish & Wildlife Service, 2001). To complicate the situation, they are extremely sensitive to distributions, especially during calving season, and must have an adequate foraging area with a stable supply of food. Nevertheless, caribou will move away from human disturbances once human activity in an area increases, even if it means altering, and thus, threatening their calving activities (see ibid). In the end, according to a 1986 environmental assessment report to congress, the US Department of the Interior recognized that drilling activity in the disputed north west corner of the ANWR could result in a 40 percent decline in the Porcupine caribou population (see NET, 2001).

Building upon the lessons from other natural gas drilling activities in the Artic, as well as other areas of the planet, it can then be stated that these activities result in some very precise environmental damage. Apart from what has been mentioned above, other biophysical consequences that will occur are the alteration of natural drainage patterns, changes to regional vegetation, the deflection of wildlife migration and predation habits, increased emission rates, and the contamination of soil and water supplies (see ibid). Claims that increased drilling can be done at little cost to the environment, therefore, seems highly unlikely. For instance, when asked about gas production in Wyoming's Jack Morrow Hills, Russell Kirlin, a managing executive for the natural gas company Questar, was quoted in the New York Times as stating, "you can't have Wyoming be a pristine, untouched area and still be a major natural gas producer. You have to decide what you want" (see Jehl, 2001).

Unfortunately, in most cases, people are not even given the option of making this decision.

Security Concerns

Natural gas poses an interesting security question for national governments. Its production, as has been mentioned, will inevitably lead to many of the same waste, pollution, and environmental problems related to oil production. Concern over supply can also create conflict and geopolitical issues for policy makers. However, its "cleaner" than the other fossil fuels status, ultimately makes it a necessary element of future energy systems. Most significantly, the role it will play in the development of transition technologies, such as fuel cells and hydrogen hybrid engines, will dramatically alter the global dependency on oil consumption (see OECD, 1999).

Paradoxically, it is the dependency upon a constant flow of energy sources, which developed with the fossil markets, that now creates the most salient security threat for the 21st century. As the developed world moves deeper into the new age of technology, the need for a constant supply of energy - especially electricity - becomes more essential (see Flavin and Dunn, 1999). In other words, the supply threat that modern industrialized governments use to justify large-scale fossil fuel development is, in fact, the most immediate energy system threat. With dependency on electronic computer systems the threat of any interruption becomes a very real danger (see ibid). Even a momentary loss of power could shut down entire production systems or destroy invaluable information. But, large scale production systems, such as is found with the fossil fuel infrastructure, are far more vulnerable to shocks and interruptions than smaller localized supply sources.

Seth Dunn (2000) points this out in his analysis of micro-power systems. He argues that, electrical supply systems, when originally designed were to be developed on the small-scale regionalized level. But, with the development of industrial markets and economies of scale, also came large-scale electricity producers. Today, however, this large-scale mentality is quickly becoming outdated and inefficient. Small and modular technologies, such as microturbines, solar cells, and fuel cells, can now offer adequate power generation. More importantly, they can also offer a stable supply. But, as Dunn argues,

> with the large central model in mind, a plethora of subsidies for fossil fuel energy - worth at least $120 billion annually - regulations, and other policies render today's power markets essentially blind to the benefits of small-scale systems, making it hard for them to compete. (p.9)

Herein lies the security issue for natural gas. For this is a fuel source that can very effectively power microturbines and help to create hydrogen for fuel cells. Nonetheless, if the large scale production of this fuel source continues to be developed according current infrastructural consumption patterns and needs, any possible benefits will be negated by the continuing stress fossil fuel consumption places on modern energy systems.

F. Nuclear Power

Long troubled by past accidents and political fallout, nuclear power is still with us and may in fact provide increased electric power generation in the future. The most attractive element of nuclear energy for policy makers is the argument that nuclear power reactors have the potential for a zero-emission standard. However, the largely publicized adverse effects of radioactive waste production and nuclear weapon programs have created a political environment that greatly limits the large-scale acceptance of nuclear energy as a legitimate power source (especially in the industrialized world). In fact, current projections see nuclear energy's share of global TPES consumption actually falling from 6.6 percent in 1999 to 3.7 percent in 2020 (see IEA, 2001), which represents an actual decrease in productive output of 24.0 Quadrillion BTUs to 22.5 Quadrillion BTUs (see EIA, 2001). Nevertheless, to help address the environmental and political concerns of safety and waste production, nuclear programs around the world have devoted substantial amounts of R&D, including what many critics complain are unwarranted subsidies, to the advancement of emerging technologies that can improve the efficiency, stability and reliability of nuclear power plants (IEA, 1997; Elliot, 1997).

It has also been argued that emerging nuclear technologies can possibly provide a sustainable, and somewhat renewable, energy source. Most of the hope for these new technologies has been placed on the development of breeder reactors and nuclear fusion technologies (see ibid). It is contended that breeder reactors can reduce the consumption of uranium, consequently extending the life of reserves and reducing waste production. This is done by converting "otherwise 'non-fissile' (i.e. non-fissionable) uranium into plutonium, thus generating or 'breeding' some new fissile fuel" (ibid, p.66). To create plutonium, previously used uranium must be chemically treated in order to separate the plutonium from the other waste. This, in turn, produces secondary waste, albeit at lower levels than the original process (see IEA, 1996a).

The threats of plutonium use, however, have long been a major concern for both national governments and the general public. For example, in 1977, then US

President Carter imposed a moratorium on the use of breeder technology because of his concerns over the security threats arising from plutonium proliferation. But, by 1994 approximately 50 tons of plutonium was produced by civilian reactors alone, enough to arm over six thousand missiles (see Imboden and Jaeger, 1999). Critics argue that the negative human environmental security consequences of plutonium misuse could be so enormous that it must be considered the most dangerous substance on the planet (see Williams, 1998). It is therefore hard to measure the possible dangers of increased plutonium production against the benefits of non-GHG-based energy production.

The long-term benefits of fusion technologies, on the other hand, are promising in theory but, to date, "no fusion reaction has been sustained for more than a very short period of time" (Elliot, 1997, p.75). If successful, the process would fuse together atoms, likely in a form of hydrogen, at very high temperatures (approximately 200 million degrees Celsius) to create helium. It would then be followed by a release of much larger amounts of energy than that of fission. Fusion is the principle behind the hydrogen bomb, and it fuels our source of warmth, the sun (see Glanz, 2000). It is also considered a far more environmentally benign power source because its basic fuels, deuterium and tritium (both of which are isotopes of hydrogen), are relatively abundant. In addition, any atmospheric pollution and emissions would be negligible, land use would be limited and the potential for biological hazard would be extremely small (see IEA, 1997). The materials and equipment in the reactors would be highly radioactive but would also have a half-life of around ten years.

That being said, fusion technologies are, at best, several decades away from becoming a viable option (IEA, 1996a). Until then, current fission technologies will continue to be the only nuclear power source. But, growing concerns over the consequences of global warming may result in the greater exploration and use of the nuclear alternative. The French, for example, argue that since the large-scale implementation of their nuclear power program in the 1980s, which currently accounts for 70 percent of the electrical power generation, they have reduced their emissions of sulfur dioxide by 90 percent and carbon dioxide by 85 percent from within all electrical generation related fields (see Elliot, 1997).

Social Cost

More than any other energy source, nuclear power is the most highly subsidized of all. The reasons for this high subsidization rate are questionable at best. It has long been known that the economic capabilities of nuclear power are not very strong, and that investors are apprehensive to become involved (see FOE, 2001). Poor safety records, highly publicized accidents, and the multiple environmental risks involved with nuclear production all contribute to making it relatively uncompetitive (see GSC, 2002). Despite all this, nuclear technologies continue to be a favorite research and development project for many industrialized nations. France depends greatly upon electricity produced from nuclear power plants and plans to further develop their nuclear industries in the upcoming decades (see Elliot, 1997). Japan invests heavily in breeder technologies and places the nuclear option amongst the most important in their energy mix. Other nations like the United Kingdom, Germany, Sweden, and Canada have all expressed interest in further developing their nuclear power capacities as well (see ibid). And, most significantly, the United States plans further strengthen their nuclear option in near future (see Cassady, 2001).

The Republican energy bill, H.R.4, plans to hand the nuclear industry over 2.7 billion dollars in tax breaks and government subsidies, in spite of the weak economic potential of these technologies (see GSC, 2002). One example of this, H.R.4 authorizes 10 million dollars to be spent on research concerning reprocessing of the 'transmutation' of radioactive waste products (see ibid). The claim is that this research will help to 'reduce' the toxicity of waste but, it should not be forgotten, that one possible outcome of transmutation procedures is the creation of plutonium, which, as was mentioned, is likely the single most dangerous substance on the planet. The significance of this move toward reprocessing technologies is that it stands in direct contradiction to previous US Policy, which bans such research because of the risk that this material could be used in weapons production (see Elliot, 1997).

H.R.4 will also extend tax benefits to independent power produces that purchase nuclear power plants and eliminate the tax liability on the sale of nuclear power plants to private companies (see FOE, 2001). Doing this would extend the tax breaks generally reserved for the centralized and regulated utility companies who have enjoyed a favored market position. As such, this move will provide extra competition with the US electricity market that is overwhelmingly focused upon fossil fuel consumption (see GSC, 2002). However, in doing this, it is giving additional governmental support to a highly regulated, subsidized and environmentally dangerous industry, which has not yet proven itself as economically viable or 'supply stable' power source (see ibid).

To the north of the US, the Canadian government is also highly involved in the nuclear industry. For example, CANDU (Canada Deuterium Uranium) reactor technology is the focal point for the Canadian nuclear program, which is monopolized by Atomic Energy of Canada limited (AECL), a highly subsidized crown corporation. The government is heavily involved in all areas of the nuclear fuel cycle (with an annual allocation of approximately $100 million dollars a year) and helps to facilitate international development and trade for CANDU based knowledge, technologies and services. Currently 22 reactors are operating in Canada and 9 are in service or under construction abroad. Canada is also the world's largest producer of uranium, an industry susceptible to frequent price fluctuations and responsible for uranium tailings containing radium, radon gas, thorium, and other known carcinogens (see Canada, 2000; Canada 1997a).

Critics charge that Canada's nuclear sales have bordered on the reckless; for example, a recent sale to China took place without the usual environmental impact assessment, and was guaranteed by way of a loan from the Export Development Corporation (see Martin, 1996). In addition, many of AECL's clients, such as Argentina, Romania, South Korea, Turkey, and Pakistan, have had dubious human rights records (however, this is certainly not a connection unique to nuclear exports). While policymakers struggle with various, but always unappetizing, options for nuclear waste storage in the Canadian shield, it may be even less likely to expect such states to deal with their own storage problems. There are further concerns about Canada's willingness to import over 100 tons of weapons plutonium from the United States and Russia for processing in the next 25 years. In short, though the current understanding amongst policy makers is that the zero-emission potential of nuclear power could possibly lead to an increase in international motivation for expanding its production, especially in areas where gas and hydro are not readily available (see Radetzki, 2000) other political considerations will weigh heavily upon the nuclear option.

Environmental Cost

The dangers of nuclear power and technologies are well publicized throughout the world. These dangers have been highlighted by the large amount of international attention that is drawn to accidents when they occur. Most notably, the major accidents at Chernobyl in 1986, Three Mile Island 1979, and the Windscale fire in the UK in 1957 have all resulted in a great deal of international criticism (see Elliot, 1997). The nuclear industry claims that these are isolated events and that new safety procedures, which were developed through the lessons learnt from these incidents, have now decreased the chances of such an event occurring again.

Assuming that this is true, the question that still remains is "are the risks worth the benefits?" A review of the various energy technologies presented in the journal of *Nuclear Energy* points out that "for a 10 percent core release from a typical PWR, total mortality of approximately 10, 000 people is expected in a typical Western European location with appropriate counter measures" (Eyre, 1993, p.324). This article goes on to explain that, given historical experiences with most types of reactors, the probability of an accident is once every 1000 Giga Watt (GW) years, which sounds like a long time. But, as David Elliot (1997) points out once you take every reactor currently operating into consideration, the probability of an accident rises significantly. For example, 100 reactors each operating for 1GW would increase the probability of accident to once every 10 years. And, if the world moves further toward nuclear power use, these chances logically increase.

Now, clearly the age of each reactor must be considered in this equation because the chances of new reactors having trouble is significantly lower than older reactors. That being said, numerous reactors around the world have been operation for along time and require much more money and time to maintain than the younger reactors (see IEA, 1997). Most notably, reactors found in the former Soviet Union are aging and require investment in order to keep operations safe. But, many of the countries that now use these reactors, such as the Russian Federation or the Ukraine, cannot afford the necessary costs to maintain them, which becomes a very dangerous-situation once it is understood that the electricity they produce is an essential aspect of life in these countries.

The waste products produced from nuclear power plants are another major concern for national governments. Adequate storage facilities must be constructed for these waste products, which are highly radioactive (IEA, 1997). The concern for these facilities must not only focus on the simply disposal of these products, but must also be able to prevent any leaks or natural contamination for thousands of years. Plutonium, for example, has a half-life of around 25,000 years and, for its radiation levels to fall to what can be considered safe, would take about 250,000 years (see Elliot, 1997).

Finally, the fuel cycle itself for nuclear technologies is very energy intensive. For example, to acquire the minerals need to produce nuclear reactions, namely uranium, requires a process similar to that of coal mining - though it involves less surface mining. Many of the pollution and contamination problems found at coal mines are also found at uranium mines, compounded by the added danger that uranium is, in itself, radioactive. Uranium is also a finite mineral, more so than coal, oil and gas. Increased nuclear power production must then also contend with resource scarcity issues. In addition, the transportation of these minerals, both before and after processing, requires a certain amount of fuel consumption and safety regulation. Therefore, once all the threats and environmental costs are considered, not to mention the fact that nuclear technologies are not economically competitive with other fuel sources, it seems that the nuclear option is not a wise choice.

Security Concerns

Clearly, given the volatile nature of nuclear technologies, the security concerns surrounding the nuclear industry are well deserved. Especially, the threat of a hostile member of any given social group or country attacking a nuclear facility must be paid heavy consideration. The security measures taken to prevent any accident or attack upon a nuclear power facility, and its corresponding infrastructure, must be very significant. In addition, the danger of nuclear weapons production must be a primary concern for anyone contemplating the Security Concerns of nuclear power.

That being said, there is a very large body of literature published concerning issue such as these, most of which, falls under the banner of national defense and security - in terms of military aggression and geopolitical concerns. This is, nonetheless, a debate that falls beyond the scope of this thesis and will not be addressed beyond this very brief discussion. However, given the high requirements of security, regulation, and subsidization, combined with the immense threats to the environment and the low economic capacity of nuclear power, it seems obvious that this energy option cannot offer benefits above its socio-political price.

G. Conclusion

In the end, by looking to the many social, environmental, and security costs that result from the modern fossil fuel system, the most significant goal that is accomplished is that a solid foundation is established, upon which a study of alternative energy sources can be built. Most notably, the growing level of uncertainty pertaining to future energy related problems helps to place the "business-as-usual" scenario under question. Put simply, as was mentioned above, once the notion of an energy system, with both biophysical and social externalities being considered, is incorporated into the conceptual framework of fossil fuel use, the lack of an alternative seems very precarious. It can, therefore, be argued that the need to find energy sources, which help to mitigate or correct this problem, is an essential aspect of any complete energy system based study.

Chapter Four

"Realizing the Potential of Renewable Resources"

A. Introduction

By almost all accounts, the fossil fuel era will inevitably be coming to end sometime during the next century. Some analysts, such as Christopher Flavin and Seth Dunn (1999), believe that this end will come much sooner than mainstream projections announce. They point out that many large oil and automobile companies have recognized that the final limitations to global fossil reserves will be reached in the near future. Consequently, these companies are beginning the slow process of shifting investment, research and development into newly emerging energy markets - most notably renewable technologies such as solar, hydrogen fuel cells, and wind. Here, it is recognized that the potential of renewable energy sources lies in an ever-increasing market potential and an adaptability that allows them to be implemented throughout the world without the need for large centralized distribution systems (see Dunn, 2000a, Brown, 2001). Furthermore, a shift to renewables would greatly reduce fossil fuel dependence, increase supply security, and prevent environmental degradation.

In this, the need for a 'soft approach' to energy consumption is becoming more and more immediate every day. The social viability of this can be seen in the continuing move toward, and social desire for, energy efficiency throughout the developed world. Building upon this, Amory Lovins and Chris Lotspeich (1999) maintain that it is now time for this newly emerging mentality to also incorporate the notion of ecological efficiency. They also contend that now is the time to establish a new 'energy ideology' that is based upon natural capitalism. With this, it can realized how large investment in renewable energy resources today will bring enormous savings in the future (see Brown, 2001).

Nevertheless, developing an alternative global framework to end dependence upon fossil fuel consumption is an incredibly complex undertaking that touches upon every element of socio-political life (see Flavin and Lenssen, 1994). Especially, given the structural support for the fossil fuels, which they must compete against[1]. Nonetheless, there are those who argue that the answers are "as old as the sun, as abundant as the wind, and as close as the earth itself", which are obvious references to solar, wind, and geothermal power (Ginsburg and Aston, 2000, p.134). Given the normative context of an international economy based overwhelmingly on the industrial dominance of the energy sources described in the previous chapter, this is a hard sale. However, when we consider, in their entirety, the vast array of negative ecological consequences arising from fossil fuel consumption (see Davison, 1989), the enormous potential of renewable energy sources gains in attraction (see Brown, 2001). Simply put, renewables do not have a naturally-occurring finite limitation. That is not to argue that they are beyond criticism by the ecologically sensitive; nor that their utilization does not pose genuine human rights dilemmas, especially when one looks to large-scale hydro developments. Yet, when examining the "business-as-

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[1] In his recent 2002 budget proposal to congress, US President George Bush announced his intention to reduce the funding to renewable energy programs by $186USD (a drop of over half from the previous budget). Instead, he has opted to increasing funding to technologies like clean coal process and give more tax incentives to electricity producers. One of the arguments the Bush administration has used to justify these cuts is that they could use an assumed $1.2 billion USD in bids for oil and gas leases in Alaskan Artic National Wildlife Refuge to help further fund alternative energy development. (see Doggett, 2001).

usual" scenario (see OECD, 1999), it is blatantly clear that these options must be considered.

Therefore, by building upon the need for change, as was established in chapter three, the following chapter will now look to the basic situation renewable resources currently face. In this, a descriptive analysis of the most prevalent renewable resources will quickly be detailed. As such, the technical and structural characteristics of each energy source will be elaborated upon, so as to provide a better understanding of the conversion method being described. This will help to place each of the renewables within the context of both contemporary systemic needs and available social knowledge, as is now understood within the broader framework of an energy system study. This will, thus, clearly help to establish the potential of the renewable energy sources as a viable alternative to fossil fuels. The environmental and biophysical benefits of each source will then also be detailed, so as to further advance the notion that renewable resources can help to mitigate many of the larger ecological and entopic problems caused by fossil fuel use. Finally, the potential to supply a continuous and stable flow of energy, so as to feed the growing energy needs around the world, will be discussed.

In doing this, hydro, geothermal, and biomass energy sources will first be briefly presented. Next, solar, wind, and hydrogen/fuel cell energy sources will be more extensively evaluated, for it is these three sources that hold the highest degree of technical, economic, and ecological potential. In the end, it is hoped that the possibility of these energy sources playing a significantly growing role within global energy systems will simply be established - for with this, future studies that begin from this basic premise can then be initiated. That being said, it is now time to focus on this depiction of the renewable energy sources.

B. Hydro

Hydroelectricity is generated by converting falling water into energy in the form of electrical power through the use of mechanical turbines and generator systems. The concept, based on an ancient technology, simply captures the natural energy found within the flow of moving water for human use. Most large-scale hydro developments in OECD countries occurred at a time when huge infrastructural projects were presumed to be the most cost-efficient manner to distribute electricity to large grids (see Wohlgemuth and Missfeldt, 2000). Such projects transform the rivers they block, creating a huge reservoir above the dam, shifting fish migration patterns, and causing siltation and other factors related to human efforts to control river flow, speed, and volume.

The attraction of these projects is that reservoir facilities offer storage capacities that can last for periods up to a few months (depending on the rate at which the water is allowed to pass through the turbines). Further large-scale development of hydro resources is limited throughout the globe by a slowing rate of technological advancements in the field (the modern industry is a relatively mature one), fewer geographical locations suited to such projects, and the vast amount of ecological and political concerns that effect issues like habitat destruction, human rights, and international boundary disputes (see Ohlsson, 1995). Nevertheless, the potential still remains for "considerable expansion in Norway, The United States, Canada, and in many developing countries" (IEA, 1997, p.186). Rivers such as the Mekong in southeast Asia are still the target of large dam engineering and construction companies, and the provincial government of Quebec (in Canada) maintains long-term plans to expand the James Bay Hydroelectric Project.

However, the most promising route of expansion for hydro lies in the development of small-scale systems designed to accommodate basic river flow patterns; what is lost in output controllability and cost-effectiveness may be gained by lower levels of environmental impact and local ownership. Recent developments in turbine and pump technologies, which reduce costs and increase output, have also further advanced the possibility that small-scale applications could be an efficient and viable alternative (see IEA, 1997). In addition, they also allow for the flexibility of smaller amounts of investment and can currently be used as "off-grid" applications. Such technologies offer policy alternatives to governments who are concerned with GHG abatement while also avoiding the environmental issues associated with large-scale dam development. Nevertheless, expensive evaluation procedures, infrastructural barriers, and technical issues (like the diversity in resource and grid conditions) still provide significant obstacles to further developing small-scale applications (see IEA,1997a)

Tidal technologies offer another method for capturing the kinetic energy found in moving water (see Middleton, 2001). The principal method of converting the ocean motion into energy is with storage reservoirs that are filled with ocean water at times of high tide and then slowly allow this water to drop through turbine generators - basically in the same manner as large-scale hydro systems (see IEA, 1997). There is limited potential, however, to the application of tidal plants, which are restricted to suitable geographical locations. Other research is being done for technologies that generate electricity as tidal water passes through various systems, without the use of storage facilities, but these technologies are still in the infancy stages of development and could threaten delicate marine ecosystems.

C. Geothermal

Geothermal energy literally means "hot-earth" energy. Essentially, it is the energy found in the rock and fluids located within the earth's crust, which is believed to stem from radioactive decay occurring near the core of the planet. The levels of energy that reach the surface vary greatly depending upon many geological factors, all of which serve to ultimately limit the use of geothermal energy. That being said, it also believed that the total heat found within the earth's surface is approximately equal to 50 thousand times more energy than that of oil and gas reserves (see Canada, 2000). In theory there are a variety of ways in which this energy supply could be used, such as geo-pressurized, hot rock, and magma technologies, but effective methods have yet to be developed. Currently the most widely used energy systems are hydrothermal and earth energy applications.

These resources can be classified into three different groups: low, moderate and high temperature. It is the high temperature systems (150°C and above) that are used for the generation of electric power but the potential for this depends greatly on a region's geothermal activity and the subsequent capacity to extract heat from the earth. The low (less than 90°C) and moderate (90°C - 150°C) temperature activities are available in a much larger range of geographical locations but their output potential is also much lower (see IEA, 1997; IEA, 1996a). Two examples of the applications used from low range source are direct use and ground-source heat pumps. Direct use systems heat buildings by using the temperature directly found in water (without the use of a heat pump or heating device) by simply drawing it out of the ground and sending it through a piping system (see ibid). Ground-source pumps use the earth as a heat source or sink depending on seasonal needs. Of course, electrical energy must be used to power the pumps for these systems, but they typically "generate three to four units of energy output per unit of energy input" (Canada, 2000, p.107).

When looking to the United States, Geothermal energy currently supplies 6 percent of the electricity produced in California, 10 percent in Northern Nevada, and 25 percent for the island of Hawaii (see UCS, 2001). With this current power production, and enhanced investment in technology development, the US Department of energy estimates that geothermal energy production could be increased ten-fold. This increase could supply 10 percent of the total energy requirements for the western states (see Wright, 2000). Currently, the US generates 2700 megawatts of electricity, which is the approximate equivalent of 58 million barrels of oil (see ibid). The average price of this generation lies between 4 to 8 cents per kilowatt hour, but the industry believes it will soon achieve a rate of 3 cents per kilowatt hour, which is very competitive (see ibid).

The benefits that geothermal power produces lie, most significantly, in the additional diversity it supplies to a nations 'energy mix' in an environmentally friendly manner. This diversity can only help to increase the security of supply. As Marnell Dickson (2001) points out, "Geothermal energy is a clean, renewable energy resource that can be exploited in a sustainable way. It differs significantly from other alternative energy sources in that it is independent of climate and seasons and can be operated 24 hours a day" (p.16). In addition to this, geothermal power has the potential to effectively produce hydrogen through the process of electrolysis with water. This hydrogen can then be used in fuel cells and could supply a basis for a hydrogen economy.

For example, Iceland, a country with vast geothermal reserves, has recently declared that it will use this energy source to produce hydrogen and, subsequently, shift their entire economic system to one that is based on hydrogen consumption rather than oil (see Dunn, 2000). The implications of this experiment are vast and exciting. If successful, Iceland can serves as model for other countries to build a hydrogen-based infrastructure. It would also allow other countries, and areas of the world, which have geothermal resources to follow Iceland's lead and secure the potential economic benefits from hydrogen production (see ibid). Geopolitical security issues could possibly evolve as a result of such a development, but, given the potential of other renewable energy technologies, it is highly unlikely that these issues would be as troublesome as those surrounding oil production. In all this, any increase to geothermal production, and improved research into geothermal technologies, must be considered a positive step toward the greater implementation of a larger renewable energy system.

D. Biomass

Biomass is the oldest form of exterior energy production in use, as it has been employed since the use of controlled fire. Ultimately, biomass energy production is derived from the natural process of photosynthesis, which uses energy from the sun to convert carbon dioxide and water into carbohydrates (see Cheremisinoff *et al.*, 1980). When they are burned, the carbon dioxide, water and solar energy is re-released to be used again by future biomass crops (see IEA, 1997). The principal sources of biomass include energy crops such as woody grasses, wood and wood wastes from forestry harvests, organic agriculture wastes, and industrial or municipal wastes (see UCS, 2001). In each of these cases, their market and technological feasibility as an energy source vary greatly depending upon factors such as investment and infrastructure barriers, the level of ecological effects on local environments, the level of social development, political will and market competition (see IEA, 1997e).

It is important to recognize that these vast differences also allow for impressive amounts of flexibility in the implementation of biomass within the fuel mix of transitionary energy markets, especially in the developing world, where people rely heavily upon these sources for primary energy consumption (see Barnes and Floor, 1999). The main prospects for utilizing these fuel sources lay in direct combustion, electricity production, and thermal, biological or chemical conversions to secondary fuels, such as methanol, ethanol or bio-diesels (IEA, 1994a). Moreover, these secondary fuels could play ever increasing roles in reducing the transportations sector's dependence on fossil fuels through their direct use, the use of hybrid fuels, or the production of hydrogen - to be used in fuel cells (see ibid). Despite the cultural stigma the so-called modern world might hold toward biomass sources, they are a promising alternative fuel source with widespread applicability. In theory, no new GHGs are added to the atmosphere through biomass production and consumption because a 'closed loop' is created between the carbon dioxide captured in crop production and lost in energy consumption (see Canada, 2000). Of course, these rates are affected greatly by harvest rates and waste production. Nevertheless, when compared with fossil fuel consumption, biomass can reduce carbon dioxide emissions by up to 90 percent (see UCS, 2001).

Currently, approximately 15 percent of the world's energy needs are met through the use of biomass, a number which could potentially reach as high as 35 percent to 45 percent in some developing countries (see EIA, 2001). There is no denying its natural abundance: the present "biomass production on land represents the equivalent of over one billion barrels of oil equivalent per day, or more than five times the total present demand for energy in all forms" (IEA, 1997, p.183). Humans directly consume only approximately 7 percent of this annual production, even though the indirect effects of habitat destruction, soil erosion, and the destructive effects of various forms of pollution, such as global warming and acid rain, would translate into much larger usage rates. Unfortunately, much of the remaining biomass production, found in industrial, municipal and agricultural wastes, is simply "burned off", thus providing no additional benefits (either in terms of energy or generated employment).

Douglas Barnes and Willem Floor (1999) address the issue of biomass fuels and the necessity for many people in the developing world to use these fuels as a primary energy source. In this, they are quick to recognize that environmental skepticism does surround the development of biomass technologies and the mainstream institutional acceptance of biomass as a legitimate energy source. But, in terms of practicality, biomass energies will remain a critical element of the energy mix in developing countries (see ibid). Building on this, Barnes and Floor point to various energy uses for biomass, such as the generation of electricity as it is burned, turned into a gas and used to power turbines, using it to produce hydrogen through specific electrochemical reactions, and making better use of farm and animal waste so as to supply further biomass sources.

There is, however, difficulty in researching and developing this fuel source because of a perpetual lack of market interest and investment. That being said, numerous reports have recently been published that support the market potential and efficiency level of various biomass products - most notably bio-fuels (see Kheshgi *et al.*, 2000). In addition, biomass energies could play a very important role in future energy systems as a transition energy, which will help ease the supply needs produced by fossil fuel dependency (Barnes and Floor, 1999). Therefore, better managing and protecting biomass sources is essential. This is especially true because of the growing scarcity of biomass products around the world.

That being said, biomass does offer a great deal of promise, in terms of a future renewable energy system. It is currently the world's fourth largest energy resource, which sits after coal, oil, and natural gas (see IEA, 2001). As an agricultural product, and by-product, it also offers an economic opportunity for farmers around the world. And, as energy markets change, this fuel source could play an ever-increasing role. For example, modifying coal power plants could allow these electricity producers to derive as much as 15 percent of their fuel from biomass crops (see UCS, 2001). Increases in the efficiency rate of burning biomass fuels and other energy crops will also allow biomass power plants themselves to be both effective and competitive. In all this, it obvious that biomass will play an important role within the 21st century energy system.

E. Solar

Solar radiation is the planet's most abundant renewable energy source, and provides the fundamental basis for all energy production systems[2]. As a limitless power source with no geographical or physical boundaries, the seeming benefits of solar production, especially in regards to energy security and supply, are immense. In terms of modern technologies, there are two ways in which solar energy can be directly converted for human use: (1) a thermal process that collects the sun's direct heat and uses it to its maximum benefit and (2) an electrical process that converts the suns light into electricity using photovoltaic (PV) cells. Thermal processes can be further broken down into two categories: passive and active systems (see Ginsburg and Aston, 2000).

Passive solar systems simply use natural process to collect or access the suns energy, through design techniques, in order to heat, cool or light buildings and other various human applications. Active solar systems, on the other hand, collect solar radiation in order to absorb the heat and then use it to heat liquids (see IEA, 1997).

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[2] Debeir *et al.* (1991) point out that the solar flows contain 10 thousand times the amount of energy that is used by human societies.

These liquids can then be used for space and water heating by flowing through tubes within given applications. The collected solar radiation can also be intensified and used to heat liquids to very high temperatures, which can then used to generate electricity.

PV electric conversions, meanwhile, occur within silicon-based cells (see Frankl, 1998). The silicon is first refined in order to have all its impurities removed, and then doped with a form of boron (that has surplus positive electrons) and a form of phosphorus (that has surplus negative electrons). Then, once light photons make contact with these doped silicon cells the resulting movement of electrons that occurs between the boron and phosphorus is collected as electricity (see Harmmonds, 2000).

When compared to other renewable technologies, solar systems currently seem to be disadvantaged by high costs and low efficiency rates. They also must address the issue of storing the energy they produce so that it can be used at times of low solar activity. However, the cost effectiveness of solar technology has improved significantly throughout the past two decades. A combination of growing investment and the continued discovery of improved techniques, such as thin film PV cells, will help further reduce costs by as much as a factor of four in the next decade (see Frankl, 1998). For example, thin-film devices are no wider than a human hair, which offer the obvious advantages of low cost production and flexibility of application, though their current efficiency rates are much lower than silicon cells. Even more promising is the fact that solar applications can be integrated into many cogeneration techniques. For instance, PV systems could be used with passive designs to provide buildings with sun light and heated air ventilation, while producing electricity at the same time.

Furthermore, they could be used to create electricity for a process of electrolysis that produces hydrogen from water for use in fuel cells, which would also help solve the problem of storing energy (see Port, 2000).

As an established technology, solar power and electricity could also be a very promising source of energy for remote applications and homes located off any large grids, especially for people in developing countries who have limited access to both power and the resources used to create power. PV cells also offer the advantages of "low environmental impact, simplicity, modularity, long life times and low maintenance requirements" (Frankl, 1998, p.223). Nevertheless, international markets are currently limited and the public's acceptance of solar technologies as a legitimate and reliable power source is still a couple of decades away at best. But, as environmental concerns are brought to the forefront of public policy debates and energy security begins to grow as a concern for national governments, infrastructural changes will necessarily occur and solar technologies should grow in importance (see ibid).

That being said, the United States currently has some 200, 000 thousand homes that use some sort of PV solar technology, which is a market that is now expanding at a rate of 15 percent a year (see UCS, 2001). In fact, the American Solar Energy Society (ASES) reports that every major American PV manufacturer is currently increasing their production capacity (see ASES, 1999). Subsequently, further increasing the number of PV units in homes around the world would provide many cost benefits for individuals, in terms of electricity generated, once they have produced enough to pay themselves off. In other words, after an initial investment, the individuals using solar technologies would no longer need to buy power from a grid (see Flavin and O'Meara, 1998). And, as production increases, and more PV cells are purchased, the costs will become less and less expensive. Various solar designs can also be integrated into ones home so that it provides additional benefits such as more sunlight (see IEA, 1997). Finally, future designs could increases the possibility that excess electricity is used to produce hydrogen (see Port, 2000).

Solar systems also have the potential to provide power to a large grid system. However, this method of electricity production is currently less cost efficient than large coal and natural gas plants. But, ever increasing advancements in technological capacity, decreasing costs in the production of PV modules (especially thin film), and a move toward increasing the number manufactured modules will all soon see solar power become cost competitive (see Frankl, 1998). This potential is further seen in the fact that, at current efficiency rates, an area of 100 square miles of the Nevada desert could produce the same amount of electricity that is used across the United States every year (see UCS, 2001).

The many possibilities of solar power have not escaped the attention of the oil industry. In fact, major companies, such as British Petroleum and Royal Dutch Shell, have now created solar divisions and are investing in the further advancement of these technologies (see Mitchell, 2001; Maclean, 2000). Royal Dutch Shell is also working in the various developing countries, such as China and South Africa, to initiate solar power systems (see Reuters, 2001; Reuters, 1999a). And, British Petroleum has plans to slowly have their refueling stations and convenience stores completely powered by solar technologies (see Reuters, 1999). In all this, these investments are tiny fractions of the amount of money spent on developing oil technologies, but at least it is a start.

Governments around the world would be wise to also invest greater amounts in their solar technology development. Current subsidies and research investments in most industrialized nations is very limited. Nevertheless, advancements within any given nations solar industry could help them gain benefits from an ever-improving market situation. And, as environmental concerns become more and more prevalent within political agendas, having the option to move toward renewable technologies such as solar could provide an invaluable energy system option. Policies aimed at solar development could also help to offset energy insecurity and give nations a constant energy source. In addition, countries with ample solar potential, in terms of sunshine and suitable lands, could gain a clear geographic advantage. In all this, solar energy will necessarily play a very important role in newly emerging energy systems and moving toward its development will, thus, only benefit both nations and individuals who choose to employ these technologies in their power production.

F. Wind

Wind power is another ancient technology that humans have used as a clean and limitless energy source. Current wind systems have recently been amongst the most promising of all the renewable resources, with considerable recent advancements in terms of both cost and efficiency (see Kufahl, 2000). The potential for power generation is enormous, and wind can offer the flexibility, to lesser extent than solar, of meeting the needs of off-grid applications (see Kahn, 2000). The current cost of wind generation varies greatly on the size of the wind farm, the turbines themselves, and the amount of wind found in any given area. Of course, it is limited in this regard to areas of the world that receive a high proportion of relatively windy days. But, on average, the price of wind power has declined 90 percent in the last 20 years (see UCS, 2001).

The systems are designed around the same basic principles as hydroelectricity or steam-generated kinetic energy. One major advantage is that wind turbines have the added benefit of dramatically increasing in efficiency as wind speed increases - an advantage not enjoyed by competing sources. The cost of wind energy is now in the very competitive position of approximately 5 cents for every kilowatt-hour (see Ginsburg and Aston, 2000). And, as more and more energy projects are being proposed by both industry leaders and government officials, the potential for further cost reductions is projected to occur in the very near future. For example, on June 25 of 2001, U.S. Energy Secretary Spencer Abraham announced that the U.S. Department of Energy (DOE) would sign an agreement with the Bonneville Power Administration to develop seven new wind projects in the American Pacific North West (see Real de Azua, 2001). In these projects, the cost of power generation is expected to be less than 3 cents for every kilowatt hour, which is a price that is very cost-competitive with even the most efficient power generating sources, such as coal and natural gas (see UCS, 2001).

In addition, the technical efficiency standards of wind power generation have increased at rates that even the most optimistic analysts could not have predicted. Wind turbines are now being made larger and taller (see US DOE/WEP, 2002), both of which dramatically increase their efficiency and economic capacities. Put simply, the larger (and taller) the turbine, the more electricity it can generate (see CanWEA, 2002). This obviously increases the profit to maintenance ratio, reduces the amount of land needed, and, most importantly, allows for access to quicker, and thus, more efficient wind speeds. For instance, simple physics demonstrates that wind speeds increase proportionally to the height in which they are locate above the planets surface. So, as wind towers are made taller and larger, they are then given the ability to capture the much higher efficiency levels of power generation that these quicker wind speeds can produce (see ibid). As a result of these technical gains, investment has been attractive and, subsequently, the industry grew at an average annual rate of over 25 percent a year throughout the 1990s (see Kufahl, 2000), which is a rate that is projected to increase even more over the next decade. Consequently, as we now enter the 21st century "[a]nalysts, policy makers and industry players all recognize the attractive environmental attributes of windpower" (Kahn, 2000:16), not to mention the promising economic attributes as well.

Wind, as with the other renewable resources, can also be designed to act in collaboration with other technologies to help reduce the threats of security and supply. At the same time, it can offer greater amounts of flexibility as a modular technology, which makes it even more attractive to "risk adverse" creditors and policy makers. In North America, many ranchers and farmers have also enthusiastically addressed land issues by leasing their land to utility companies as a method to supplement their incomes.

As Robert Kahn points out, a typical wind farm "takes no more than two percent of farmland out of production. Cattle graze right up to the turbine foundations and row crops can be placed nearly as close" (2000, p.17). This could supply individual landowners with revenue of $2000 a year for every turbine in use on their property (see Kufahl, 2000) These low cost applications and supplementary income generating possibilities could also be applied within the developing world.

In all this, wind power is quickly becoming the favorite renewable resource for governments and industry leaders alike. In Europe, Germany, Denmark, and Spain have all invested heavily in wind technologies and can, therefore, be credited with a great deal of the growth that is now occurring in global wind markets (see Editorial, 2001). Clearly, these three countries, as well as many others within the European Union (EU), have accepted wind power as a legitimate and vital component of their energy mix. And, as the EU continues to aggressively pursue green energy goals, the wind industry growth rates will soon see this power source become a mainstream power source (see EEA, 2001). For example, wind power is projected to supply as much as 25 percent of Germany's power needs by 2010 (see ibid).

The United States has also witnessed a surge in the development activity surrounding wind generation. In fact, as of March of 2001, 2000 new megawatts (MW) of wind power were being proposed. This would see the total wind generation in the U.S. jump from 2550 MW in the year 2000 to over 4000 MW in 2002 (see UCS, 2001). In addition, wind power is the only renewable resource (apart from large-scale hydro) that received any significant attention in the Bush Energy Plan (US NEPDG, 2001). In fact, it has received enough attention to garner a legislative bill

(HR 2322), which will allow for a 30 percent tax credit for home owners and small businesses who install wind systems (see Blankinship, 2001). With this, it is obvious that wind power is now, albeit slowly, achieving mainstream acceptance within U.S. energy systems.

Other industrialized countries, like Canada, who have extensive fossil fuel resources, as well as renewable resource potential, have not yet pursued their renewable resources capabilities, such as wind development, quite as aggressively as those countries who experience fossil fuel scarcity. Nevertheless, many of them, such as Canada, are in an excellent position to do so. For example, given their financial, intellectual, and infrastructural capabilities, Canada is well suited to research and develop wind technologies (see Canada, 2000). This, combined with the extensive availability of potential sites for implementation, it would seem wise for Canadian government and industry leaders to pursue wind power as a viable energy source for the countries energy mix, both for consumption and production needs (see Fick and Vincent, 2001). That being said, there are a limited number of projects being developed in Canada. For example, Ontario Power Generation (formerly Ontario hydro) and British Energy (Canada) Ltd. are planning to open a large-scale wind plant near Kincardine, Ontario, on the shores of Lake Huron[3]. The wind farm is expected to generate just 10 megawatts, or enough to supply over 3,000 homes with electricity, but it is certainly a start in the right direction, and an indication that market forces are

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[3] There are also 10 other active wind farms across Canada, the largest of which are in Quebec (Le Nordais project, which is said to produce approximately 100 megawatts of power). See the Canadian Wind Energy Association website at <http://www.canwea.ca/production.htm>.

beginning to encourage the application of expertise and capital in this area. Canada should increase its efforts to promote this alternative energy source abroad as well.

Unfortunately, even with the excitement concerning wind power, it is not projected to significantly reduce the need for fossil fuels in the near future - this is especially true in North America (see EIA, 2001). In 1999, the U.S. government, under the Clinton Administration, stated that "wind energy would supply at least 5 percent of the nations electricity needs by the year 2020" (Real de Azua, 40), which is a "far cry" from Germany's projection of 25 percent in 2010. However, even at this, the current officials at the U.S. DOE, and various influential economic policy analyst groups, such as Wharton Economic Forecasting Associates, see this projection as being overly optimistic (see ibid). In this, they point out that the present share of the electricity market in the U.S. held by wind is only 0.3 percent, which would need to increase 40 fold if it were to reach 5 percent (see ibid; EIA, 2001). And, given the current market situation, with the dominance of fossil fuels, it seems that the Clinton Administrations projections will not be achieved.

Nevertheless, wind power remains an exciting and capable renewable resource for future energy needs (see McGowan and Connors, 2000). It is now an industry that offers industrialized nations a truly capable alternative that can be used today (see Ayers, 2001a). In addition, its ever-increasing "cost-capacity" also makes it a viable alternative for developing countries, which lack a developed energy infrastructure. Future policy directions of the various global governments remain to be seen, but present developments clearly indicate a promising role for wind in the 21st century.

G. Hydrogen and Fuel Cells

Of all the renewable energy sources, hydrogen based technologies are by far the most promising. As has been demonstrated, the other renewable sources have immense potential to transform energy production and consumption, especially solar and wind, but hydrogen has the potential to completely transform society, as we know it (see Ayers, 2001). In other words, the nineteenth century science fictional dreams of a world powered by the most abundant and lightest element in the universe, as was envisioned by authors like Jules Verne (1962), is now becoming a twenty first century possibility. Accordingly, hydrogen production, and hydrogen technologies such as the fuel cell, will be examined in greater depth at this time.

The hydrogen fuel cell, which is a technology that was discovered "five decades before the internal combustion engine" (Flavin and Dunn, 1999a, p.178), has the potential to produce electricity while producing no other emission than water vapor (Jensen and Ross, 2000). In addition, unlike batteries and other storage technologies, it can produce electricity on demand through the conversion of various fuels at very high rates of efficiency. Furthermore, the cells would never need to recharge because, just as the combustion engine, they are powered by fuel (see Mazza, Roth, and MacGill, 2000). And, like solar and wind, it is also a flexible and modular technology. For example, fuel cells can be used to power commercial buildings, supply base-load power to industrial complexes, power transportation vehicles, and heat individual homes. They are also twice as efficient as conventional combustion engines, create negligible noise pollution, and require minimal maintenance efforts because they have no moving parts they have enormous potential for many supplementary activities, including large and small-scale grid applications (see OECD, 1999). In the United States, if "all cars were totally equipped with fuel cells, this would provide five times the generating capacity of the national grid" (Lahidji, *et al.*, 1999, p.20). Selling electricity back to various grids would thus help significantly defray the cost of fuel cell implementation. Unlike the combustion engine, the fuel cell actually generates power in the form of electricity. Fuel cell vehicles (FCV) could, therefore, generate electricity for commercial buildings, residential homes and industrial complexes if they were "plugged into" various grids when they are stationary, which could also generate supplementary incomes for FCV owners (see Ayers, 2001a; Srinivasan *et al.*, 1999).

The manner in which the fuel cell works is basically the opposite of the electrolysis process of splitting water molecules into hydrogen and oxygen. Rather, it creates electricity by recombining hydrogen with oxygen and then uses the subsequently released chemical energy to maintain a charge within the cell (see Jensen and Ross, 2000). It is hydrogen, therefore, that essentially powers the fuel cell, which then operates as a battery. Hydrogen, however, is not a primary energy source like fossil fuels or the other renewable energies. It is an "energy carrier" that is mostly found in the form of bonded energy (see Dunn, 2001). To use it then, it must be released from its bonded form, such as is done via electrolysis. Once this is done, the largest obstacle that hydrogen production must face is its transportation.

Unfortunately, the infrastructure of the both the developing world and the developed world is not yet established for the transportation and delivery of large amounts of hydrogen (see Ogden, 1999). In addition, market acceptance of this technology is also only beginning. For example, most of the largest automobile companies will only now be introducing fuel cell vehicles over the next couple of years. Residential applications are also just beginning to be used, such as a stationary generator that was just introduced to the Japanese residential market by Ballard Canada. General Electric will also start selling "plug power" systems in 2001 (see Barlow, 1999). That being said, the incredibly promising nature of fuel cells and the potential for clean hydrogen production continue to lead increasing numbers of experts to believe that hydrogen could become "as dominant and energy carrier in the 21st century as oil was during the 20th" (Flavin and Dunn, 1999a, p.178).

In fact, stimulated by growing concerns for the environment, and the ever increasing threat of fossil fuel based energy insecurity, the concept of a hydrogen economy is quickly moving beyond the realm of scientific dialogue and into the lexicon of socio-political debate (see Ayers, 2001a). In addition, recent advancements to fuel cell technologies, and the initiation of serious research investment, all help to ensure hydrogen of a predominate position in future energy economies. Put simply, the question is no longer whether or not global energy systems are moving toward hydrogen as a primary energy, but is rather how long this move will take (see Ogden, 1999; Magada, 2001).

Interestingly, much of these recent advancements and investments in fuel cell technology, and the subsequent potential for hydrogen use, has come from within the automotive and oil industries. Every major automaker has transferred research and development funding into the advancement of fuel cells (see Dunn, 2001). For example, Daimler-Chrysler will spend 1 billion dollars over the next 10 years so as to make their fuel cell powered car competitive. General Motors plans to begin mass production of FCVs by the end of this decade and also intends to be the first automotive company to achieve a level of one million sales (see ibid; Reuters, 2001a). In addition, Ford has joined forces with Ballard Power Systems in order to put fuel cell powered buses on European streets in 2002 (see Dunn, 2001). And, most significantly for industry analysts, Toyota has recently announced that it will begin selling fuel cell powered cars within the Japanese market by 2003 (see ibid).

In turn, the major oil companies, such as Royal Dutch Shell and British Petroleum, have created new hydrogen divisions so as to allocate the necessary funding and management to the development of this key energy carrier (see Dunn, 2001). Texaco is now investing heavily in technologies that advance hydrogen storage capacity, in an attempt to break into this emerging infrastructural market (see Gardner, 2000). And, Exxon Mobil has joined with both GM and Toyota in order to further develop fuel cell technology (see Ellis, 2000; Chatterjee, 2001). All of this is an obvious indication of how important these companies believe the future of this technology to be.

Nevertheless, governments around the world, especially in North America, continue to move further toward high dependency on the fossil fuel based economic system (see Cassady, 2001; EIA, 2001). The primary reason for this is the perceived barriers to building a renewable resource and hydrogen based infrastructure (see Jensen and Ross, 2000; Ogden, 1999). Most notably, the design of FCVs, the storage capacity of hydrogen, and a refueling infrastructure are all currently too expensive and not yet efficient enough. The first two of these barriers, however, are quickly being overcome, especially given the investment mentioned above. But developing a refueling infrastructure continues to be a significant obstacle for government and industry alike (see Jensen and Ross, 2000).

For obvious reasons, refueling is an essential component of fuel cell development and FCV production. Industry leaders, nonetheless, are understandably hesitant to "mass produce vehicles that could only be refueled at a few locations" (ibid, 12). At the same time, not very many people are willing to invest in developing a network of refueling stations if FCVs are not on the market. Consequently, the dilemma of the refueling barrier leaves both policy analysts and investors within a "catch 22" situation, or what Jessen and Ross (2000) refer to as the chicken and egg infrastructural dilemma.

Possible solutions that are being proposed are to "piggy back" of the current natural gas industry, and its distribution and hydrogen production system, in order to get an adequate level of hydrogen refueling sites in place (see Ogden, 1999). Producing hydrogen by reforming natural gas is currently the most common method used. Much of this is done in order to create the ammonia (NH3) used in fertilizer, but this process could also be expanded so as to produce enough hydrogen for an initial FCV fleet. In this way, natural gas must be distributed to reforming stations rather than delivering pure hydrogen throughout any given country or region (IEA, 1997b).

Along these lines, on board reformers are also being proposed as a refueling solution. With this, either gasoline or methane (natural gas) could be used. However, the use of on board reformers is not "an optimal vehicle configuration, and it does not unleash the full potential of fuel cell technology". But, what is does is "serve to introduce fuel cell vehicles to the general public while building production, operational, and maintenance experience with fuel cell engines" (Jensen and Ross, 2000, p.15).

The problem with these solutions, even though they aid in the transition toward a hydrogen economy, is that they further advance the need for natural gas. They also require a great deal of investment in, and further infrastructural development of, the natural gas energy system. Such a move will appear foolish once alternative methods of hydrogen production become cost effective, which is not a long term or unrealizable goal given current efficiency improvements to the electrical generation capacity of renewable resources (see Flavin and Dunn, 1999).

Most significantly, as was mentioned, both solar power and wind power are making considerable progress in their abilities to efficiently generate electricity (see Brown, 2001). Therefore, these resources could use this increased capacity to produce hydrogen through the process of electrolysis. In fact, energy analysts argue that a proportion of the land currently used for solar energy production within the southern United States could produce enough hydrogen to fuel the countries entire 200 million vehicles (see Jensen and Ross, 2000). This option becomes even more exciting when considering the vast tracts of land that cold be used to produce solar energy. Building on this, Seth Dunn (2001) points out that the entire projected global energy demand for 2050 could be met through the solar hydrogen production that only uses 0.5 percent of the worlds land area. This is much less than what is currently dedicated to fossil fuel production (see GSC, 2002). Furthermore, biomass and municipal wastes can also be used in hydrogen production through gasification technologies, which could also supply alternative fuel sources that reduce fossil fuel dependency and aid in the transition to a hydrogen energy system.

Given this, the cost of developing a hydrogen infrastructure is widely debated. Some very conservative estimates claim that the financial commitment of such an endeavor could reach as much as 100 billion dollars in the United States alone. But as Seth Dunn (2001) demonstrates, developing a pure hydrogen infrastructure would cost less in the long run than adapting current infrastructural needs so as to take an interim path. And, even at the most conservative estimates, it costs 200 billion dollars less than the annual 300 billion spent on subsidizing fossil fuel initiatives (see FOE, 2001). In addition to this, Dunn (2001) argues that equipping every single gas station in the US with hydrogen dispensers would only require an investment of 20 billion dollars, which is 10 billion less than the amount spent on developing the Internet in 1999 alone.

If governments and policy makers decide to ignore the immediate possibilities of hydrogen production, choosing rather to think of it as a future energy resource (as it is understood in the current US energy plan), they run the very real risk of eclipsing many possible socio-political benefits (see Ayers, 2001). On the other hand, countries and companies who choose to pursue these possibilities allow themselves the ability to tap these benefits. For example, the commercial, political, environmental, and social benefits that will be derived from hydrogen technologies will transform energy use in ways that extend beyond the current understanding of energy markets (see Ayers, 2001a). Put simply, fuel cells could replace internal combustion engines, power plants, large energy grid systems, and even small items like the portable batteries used in electronic equipment (see OECD, 1999). These changes would have immeasurable effects on political regulations, public spending schemes, production processes, and individual energy needs. It would also dramatically re-structure the very concepts of energy security and social necessity. Most significantly, the environmental and health benefits obtained by reducing, or even eliminating, the fossil fuel energy cycle are countless. Ignoring all of this is more than imprudent, it is fundamentally detrimental to the notion of social prosperity.

Just as aggressive American polices toward oil production contributed significantly to their growth in economic and political power throughout the twentieth century, countries that now move quickly toward hydrogen will place themselves in a very opportunistic position for the 21st century (see Dunn, 2001). Germany is an example of this, with their very aggressive stance toward hydrogen technologies, FCVs, hydrogen refueling stations, and renewable energy systems. They, thus, provide a strong illustration of how a highly industrialized nation can implement such policies to their benefit (see ibid; Reuters, 1999b). Japan has also taken on a very ambitious hydrogen initiative by planning to spend 4 billion dollars in the next two decades so as to develop a comprehensive hydrogen infrastructure. In this, they plan to spend up to a billion dollars over the next five years (see Dunn, 2001). And Iceland, as was mentioned previously, plans to completely replace their fossil fuel economy with that of the world's first hydrogen economy (see Dunn, 2000). The incredible potential for the developing world to leap frog the need for fossil fuels is also very exciting. Many countries have yet to fully establish an extensive fossil fuel infrastructure and, therefore, can by pass it with a shift toward hydrogen development (OECD, 1999). However, in North America, the political rhetoric and policy directions are firmly locked into fossil fuel initiatives. But, given the current problems with the environment, growing energy security concerns, and the social cost involved with this energy path, it seems that these choices need be re-examined.

H. Conclusion

Therefore, it can be argued that there is an enormous amount of potential for developing a renewable energy system. In fact, given the current levels of development occurring within the various renewable industries, as has been detailed above, it seems highly unlikely that these energy sources will not be a fundamental element of future energy systems. The dilemma, however, is once again the structural dominance of the fossil fuels. Nevertheless, as the many problems created by fossil fuel consumption become more obvious, the renewables will clearly continue to gain in popularity. Most notably, solar, wind, and hydrogen will persistently occupy an ever-growing share of energy system needs. With that being said, once a complete energy system analysis has been established, and the full context of fossil fuel use is understood, by not immediately pursuing renewable energy development government and industry leaders are simply made to appear foolish. Thus, in providing an energy system based analysis, as was detailed above, it is hoped that this essential realization will be built upon in the very near future.

Chapter Five

"Conclusion: Making the First Move Toward Properly Understanding a Renewable Energy System"

Traditional energy analysis would see a transition to the overall system occur once the scarcity of a given resource demanded that energy transformation techniques look for change. Debeir *et al.* (1991) argue that the first of these changes will take place in the ability to extend the efficiency of conversion, and thus the stock of resources, as far as possible. This would, however, also indicate a clear reluctance to shift to new resources unless necessary, thereby further demonstrating the structural interests vested within any system, as was illustrated in chapter three. Nevertheless, as was argued in chapter four, it seems that resource scarcity will not be the inevitable driving force behind the next transition. Rather, it can be contended that a multitude of modern factors will all combine so as to provide the impetus for change with 21st century energy systems. Most significantly, environmental threats, rising social costs, and security concerns will all shape the next transition to renewable resources. Put simply, it will not be scarcity that impels change but, instead, the externalities produced by modern energy use.

That being said, the shape and direction of this impending transition remains a very difficult projection to make. Today, fossil fuels dominate the global energy system to such an extent that they seem virtually irreplaceable. In understanding this, the social power relations involved in maintaining the current energy structures must also be understood as an indispensable factor within the larger system. For it is these relations that help to perpetuate this same system. For example, this was examined by looking at the immense amount of social resources that are dedicated to supporting the fossil fuel infrastructure around the world. As a result, it should come as no surprise that almost all official projections see a fossil fuel future well into the 21st century. It should then also be easy to understand why modern development is focused on a fossil fuel infrastructure - the success of fossil fuel development serves to determine the success of these huge social investments. Too much social investment is now at stake, for many with influential interests, to enthusiastically pursue alternative choices.

However, it must be realized that change can occur very quickly once the factors for this change have arisen. Determining the specificity of these factors is, nevertheless, an impossible endeavor when the social and political lexicon is dominated by limited goals. To attempt and define a precise situation in which change to energy systems takes place, therefore, runs the risk of falling into deterministic analytical behaviour. The best one can do is to attempt an accurate depiction of trends that are occurring within the specifically defined context of energy use. Anything else would fall into the trap of misplaced concreteness, as was defined by Daly and Cobb Jr. (1994), and, thus, inevitably produce its own externalities. It is therefore extremely important to analyze trends within the context of the larger energy system, as was defined in the early stages of this thesis. This way, energy production can be understood within its larger social and environmental parameters. As such, the appropriate avenues (and needs) for change can be better determined. To do this, however, a general systems analysis is first essential, where all the factors that play a role within an energy system can be examined. With this, entrenched social structures may no longer appear as the only determining factor for meeting energy needs and the possibilities for change may become visible.

Otherwise, the immediate needs of energy systems, as determined by the predominate structural needs, will fail to envision all the change that is occurring within the larger social system. In the industrial age, this was first seen with the transition to coal from charcoal, and the countless developments this transition brought with it. For example, as Robert Ayres (2001) demonstrates, the 18th century need for charcoal produced many problems along with its use, such as deforestation, inflation, energy scarcity, stalled development, and economic stagnation. At the time, more progressive goals oriented toward coal use could have stimulated many of the unforeseen developments much sooner.

Nonetheless, some coal development did occur and, consequently, this led to technical improvements and benefits that could not have been envisioned by the popular thought of the day. For instance, coal mining led to the necessary invention of the steam pump, which displaced the water, found in mining shafts. This, in turn, lowered the price of coal and produced spill-over effects like the discovery of coal gas, the invention of the steam engine, the creation of boring machines, the production of locomotives, and the launching of steam driven ocean liners. All of this then led to infrastructural developments, such as cast iron and steel, railroads, bridges, coke gas, and eventually the internal combustion engine. However, at the beginning of this transition, the industrial and governmental desire to continue charcoal production could not have prepared for these changes.

Another classic example of unforeseen changes came from a publication born from the Chicago World Fair in 1893, where the best scientific and political minds located in the United States at the time were asked to project the needs of the 20th century. They saw that "the nation's streets were filled with horse-drawn carriages and illuminated at night by gas lights that were still considered a high-tech novelty" (Flavin and Dunn, 1999, p.24). This prediction also saw coal, an energy source that had only found predominance that century, as the energy source for the future. Nevertheless, shortly after this fair, the gasoline-powered automobile entered the social market place, which clearly transformed energy needs in immeasurable ways. Once again, many of the projections, based on structural dominance were proven irrelevant.

With the wealth creation and global development that has occurred over the past century, today's energy analysts again see the current system as immutable. However, the possibility of once again misrepresenting change exists just as it did in these previously mentioned cases. Interestingly, this realization has not escaped the major energy distributors of today. Energy giants, such as Royal Dutch Shell and British Petroleum are openly announcing that the end of "the oil age" is coming (see Mitchell, 2001). In part, these public proclamations are an aspect of the vigorous attempt to establish an "environmental friendly" public image. But, on deeper analysis, they also demonstrate an awareness that future energy production lies outside the hydrocarbon economy. This is clearly evidenced in current movement by these companies to invest in renewable energy technologies, as has been mentioned in this thesis.

Given the current political rhetoric of energy needs, it seems that most governments also recognize the future of renewable energy. But sadly, this is not a realization that is being translated into governmental support. Almost every industrialized nation has publicly announced that social and environmental needs alike will require the future development of the renewables. But, in large part, this development is understood as something that cannot come at the expense of the fossil fuel infrastructure. The reason for this, is first the entrenched social interest that supports the fossil fuels and, second, the belief that the renewables are not yet a viable alternative. And, financially speaking, this is a legitimate concern. But, as has been shown, the externalities that stem from a purely economic analysis serve to presently deem this an inadequate measure of possible alternatives.

Nonetheless, the economic realities of energy use continue to be the dominant influence on industrialized government energy policies. As a result, an obvious lack of initiative in renewable resource development is apparent. The problem with this, as has been extensively outlined, is that continued fossil fuel use will lead to many problems that will soon be too large to properly curtail. In addition, the enormous potential of the renewable resources to be both technically and economically viable clearly leaves one questioning the logic of not pursuing them more actively.

Clearly, the reason for this is an inadequate system of analysis that fails to consider many factors outside its own perceptual scope. So, the first step in addressing this problem is to develop an expanded framework for studying energy, which must first begin by compensating for the major externalities found within current methodologies. And, as was mentioned, this can be done by first looking to the work of ecological economists and the biophysical principles they attempt to advance within energy system analysis. As such, the potential of the renewables can be given proper consideration, while the dangers of the fossil fuels can also be properly understood. It can therefore be hoped that a general analysis, as was presented in this thesis, can lay the "groundwork" for future studies - studies that do not ignore the environmental and social threats that current energy systems pose to both human populations and the planet itself.

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