ENERGY, ENVIRONMENT & SUSTAINABLE DEVELOPMENT

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I. INTRODUCTION

This article is based on three major premises. The first is that the greatest international environmental challenge of the 21st Century is the manner and extent to which increasing global energy demand can be met within the framework of sustainable development (SD).[1] This idea underscores the fact that energy constitutes a primary life force in both developed and developing countries. The peoples of the world rely on cheap and accessible energy for transportation on land, air and water, using millions of cars, buses, trains, planes and ships. In addition, energy is essential for domestic and commercial heating and cooling in many parts of the world, as well as for agriculture, manufacturing, mining, information technology, and a variety of service industries. Furthermore, men and women the world over use a plethora of energy dependent personal devices and instruments from flashlights and laptops to telephones and watches.

Two important corollaries to this premise emphasize the pressing need for more and better quality energy especially in the developing world. First, 1.6 billion people, or one quarter of the world's population, preponderantly located in developing countries, do not have access to electricity.[2] The right of these

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[1] Though extensively and ubiquitously employed there is no canonical or authoritative definition of the open-textured concept of "Sustainable Development." It is a difficult syncopated idea calling both for economic growth and environmental protection, and it is broadly perceived as development that uses and expands the human and natural resource heritage and base in a manner that meets the needs of the present generation without jeopardizing future generations.

[2] INTERNATIONAL ENERGY AGENCY, WORLD ENERGY OUTLOOK 2002 365 (2d ed. 2002), *available at* http://www.iea.org/textbase/nppdf/free/2000/weo2002.pdf (last visited May 1, 2005).

countries to sustainable development is inconceivable without electricity. Second, 2.4 billion people rely on wood agricultural products and animal waste for their cooking and heating needs.[3] While wood and agricultural products may formally be classified as renewable biomass, the manner in which wood and agricultural products are collected, harvested and used has led to an acute loss of biodiversity and environmental degradation.[4] Consequently, if we are to meet our energy needs, and more pertinently, those of the developing world, we need to search for new sources of sustainable primary energy.

Primary energy refers to the kind of high energy required by modern humans that is found in natural resources such as coal, gas, crude oil, sunlight, and uranium and is subjected to anthropogenic conversion or transformation. Sustainable primary energy refers to energy that can be produced *without* causing significant and destructive environmental impact. Moreover, the search for new sources of sustainable energy must be paired with an unyielding and persistent thrust toward energy conservation and efficiency.

The second premise of this article is that it is not possible to move toward a sustainable energy future without new international instruments. The reference to international agreements is to a genus that could include a variety of multilateral and bilateral agreements, pacts, treaties, protocols and conventions dealing, *inter alia*, with science and technology (S&T), trade and investment (T&I), research and development (R&D), technology transfer, and SD. The task of finding new sources of energy to replace the present global reliance on hydrocarbons cannot be undertaken by one nation alone. Rather, it is a quintessentially international challenge calling for international responses. Thus, the principal objective of these instruments will be to facilitate the development of primary sources of energy, i.e. energy in its naturally occurring form, as well as energy conversion, transmission and end-use distribution.

This article's third premise is that it is necessary to provide decision-makers with a comprehensive scientific, engineering, economic and socio-political knowledge base and policy compass. This information base will illuminate pathways toward an integrated approach to the development and deployment of renewable energy through international instruments.

This article begins by making the case for new energy

3 *Id.*

4 *See* LAKSHMAN D. GURUSWAMY, INTERNATIONAL ENVIRONMENTAL LAW IN A NUTSHELL 129-32 (2d ed. 2003) [hereinafter NUTSHELL].

accords in Section II, followed in Section III by the delineation of a preliminary framework that allows for entities to enter into appropriate international agreements. Section IV addresses some questions not answered by the preliminary framework. Section V describes the need for a comprehensive treaty review that will form the baseline for the negotiation of new international instruments, and Section VI will provide a brief conclusion.

II. THE CASE FOR NEW ENERGY TREATIES

The case for new energy accords to address the challenge of sustainable energy is premised upon six widely recognized phenomena, including: (i) burgeoning energy demand, especially from the developing world; (ii) the fearful environmental consequences of using fossil fuels or hydrocarbons as sources of energy; (iii) the finite nature of oil and gas reserves; (iv) the energy insecurity caused by reliance on oil; (v) the unsatisfactory nature of the international legal response to the looming shortage of sustainable energy; and (vi) the lack of satisfactory technological, legal, economic and social mechanisms currently addressing the issue.

First, according to some estimates, today's current primary global power consumption of about 12 TW[5] will reach 30 TW by 2040.[6] Other forecasts suggest that total global energy consumption will expand by 54 percent between 2001 and 2025.[7] A significant and troubling portion of this projected increase in energy demand will occur in developing countries, which rely primarily upon the combustion of hydrocarbons, such as coal, to produce the electricity necessary to meet their energy demands.

As a result of the increasing reliance of developing countries on fossil fuels – particularly coal, which is the most carbon-

5 One terawatt (TW) equals 1,000 gigawatts or one million megawatts. *See* British Energy Website, *at* http://www.british-energy.com/corporate/safety/reports2002_03/begen_2002_03/glossary/glossary.htm (last visited May 1, 2005).

6 *See* Martin I. Hoffert et al., *Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet*, SCI. MAG., Nov. 1, 2002, at 981; Martin I. Hoffert et al., *Energy Implications of Future Stabilization of Atmospheric CO_2 Content*, NATURE, Oct. 29, 1998, at 883. Future energy scenarios are based on complex demographic, socioeconomic and technological assumptions and, thus, may vary significantly.

7 ENERGY INFORMATION ADMINISTRATION, INTERNATIONAL ENERGY OUTLOOK 2004 1, 7 (2004), *available at* http://www.eia.doe.gov/oiaf/ieo/index.html (last modified Apr. 15, 2005 [hereinafter IEO 2004]. In addition, "[t]otal primary energy consumption . . . is projected to increase from 98.2 quadrillion British thermal units (Btu) in 2003 to 133.2 quadrillion Btu in 2025 (an average annual increase of 1.4 percent)." ENERGY INFORMATION ADMINISTRATION, ANNUAL ENERGY OUTLOOK 2005, para. 14, *available at* http://www.eia.doe.gov/oiaf/aeo/ (last modified May 1, 2005) [hereinafter AEO 2005].

intensive of fossil fuels – CO_2 emissions from developing countries will be *greater* than those of developed countries by 2020 despite the lower projected energy consumption levels by developing countries. In fact, in 2001, developing nations consumed about 64 percent as much oil as industrialized nations, and by 2025 they are expected to consume 94 percent as much as developed countries.[8]

Currently, the U.S. emits considerably more CO_2 from burning oil than any other country. For example, as of 2002, the U.S. was discharging more CO_2 than Africa and Western Europe combined, and more than twice as much as the amount emitted by India and China.[9] Unfortunately, the developing countries of Asia are projected to have the strongest energy consumption growth rate, which will account for nearly 40 percent of the entire projected increase in world energy consumption through 2025. For developing Asia alone, CO_2 emissions are projected to increase from 6,012 million metric tons in 2001 to 11,801 million metric tons in 2025.[10] During this same period of time, total U.S. CO_2 emissions from energy use are projected to increase by 0.6 million metric tons.[11]

Second, the environmental consequences of using fossil fuels or hydrocarbons to produce energy are formidable and fearsome. Apart from the possibility that hydrocarbons are greenhouse gases (GHG), which may cause anthropogenic global warming, the entire hydrocarbon energy cycle of production, mining, transportation, refinement, use, and emissions is fraught with daunting environmental and public health problems. The environmental and health effects of acid rain, heavy metals, and urban smog, which are created by the mining and burning of fossil fuels, can be damaging to both developing and developed countries.

Third, oil and gas are finite and non-renewable natural resources. While their finite nature is not in doubt, controversy abounds as to the extent, and the anticipated life span, of petroleum reserves.[12] There is sharp disagreement among experts about whether the world faces an imminent oil peak followed by an inevitable decline and exhaustion of resources.

8 IEO 2004, *supra* note 7, at 3.

9 ENERGY INFORMATION ADMINISTRATION, INTERNATIONAL ENERGY ANNUAL 2002, CARBON DIOXIDE EMISSIONS FROM USE OF FOSSIL FUELS (2004), *available at* http://www.eia.doe.gov/emeu/iea/carbon.html (last visited May 1, 2005).

10 IEO 2004, *supra* note 7, at 14.

11 *Id.*

12 One thing is clear: While geologists may discover possible oil resources, they will remain in the ground until petroleum engineers can convert those resources into actual producible oil reserves.

Advocates on both sides have relied on a variety of forecasting tools, and many issues were resolved when, after a five-year collaboration with representatives from the petroleum industry and other U.S. government agencies, the U.S. Geological Survey (USGS) completed a comprehensive study of petroleum resources in 2000. The "USGS World Petroleum Assessment 2000" has been viewed as the most thorough and methodologically modern assessment of world crude oil and natural gas resources ever attempted.[13] The U.S. Energy Information Administration (EIA) responded to the USGS study by providing the first federal analysis of long-term world oil supply since the study published by Dr. M. King Hubbert of the USGS in 1974.[14]

Although the USGS is less optimistic than the EIA this disagreement is not of particular relevance on this occasion because even the EIA conclusions, are consistent with the thesis of this article.[15] According to the EIA forecast, the peaking of oil resources will occur toward the middle of the century.[16] The specific date will partly depend on the rate of demand growth because higher demand for petroleum will accelerate and advance its exhaustion.

This article argues that such demand may be reduced through technological advancements in petroleum-product usage such as hybrid-powered automobiles, and the substitution of new energy source technologies, such as Hydrogen-fed fuel cells.[17] The demand for petroleum, it is further argued, can be reduced even more drastically if international instruments are used to facilitate an increased reliance on renewable energy.

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13 *See* U.S. GEOLOGICAL SURVEY WORLD ASSESSMENT TEAM, U.S. GEOLOGICAL WORLD SURVEY PETROLEUM ASSESSMENT 2000 (2000) [hereinafter USGS SURVEY]. The assessment is available at http://energy.cr.usgs.gov/WEReport.pdf and on compact disc. A detailed analysis using the assessment appears in Alfred Cavallo, *Predicting the Peak in World Oil Production*, 11 NAT. RESOURCES RES. 187 (2002).

14 For a recent EIA presentation that references Dr. Hubbert's study, see JOHN WOOD & GARY LONG, LONG TERM WORLD OIL SUPPLY (A RESOURCE BASE/PRODUCTION PATH ANALYSIS) (July 28, 2000), *at* http://tonto.eia.doe.gov/FTPROOT/presentations /long_term_supply/index.htm.

15 While the EIA concludes that the world production peak for conventionally reservoired crude oil will be closer to the middle of the 21st Century than to its beginning, DOE's Office of Naval Petroleum and Oil Shale Reserves has not concurred with the EIA's projections and supports the thesis of an imminent oil peak. *See* John H. Wood et al., *Long-Term World Oil Supply Scenarios: The Future is Neither as Bleak or Rosy as Some Assert*, Aug. 18, 2004, *at* http://www.eia.doe.gov/pub/oil_gas/petroleum/feature_articles/ 2004/worldoilsupply/oilsupply04.html; OFFICE OF DEPUTY ASST. SECRETARY FOR PETROLEUM RESERVES, U.S. DEPARTMENT OF ENERGY, 1 STRATEGIC SIGNIFICANCE OF AMERICA'S OIL SHALE RESOURCE: ASSESSMENT OF STRATEGIC ISSUES 5 (2004), *at* http://www.fe.doe.gov/programs/reserves/publications/Pubs-NPR/npr_strategic_significan cev1.pdf.

16 *Id.*

17 *See* WOOD & LONG, *supra* note 14.

The fourth reason for new energy treaties is based on national security. Traditionally, national security has been associated with armed aggression and the ability to thwart military invasions or subversion. However, more contemporary concepts of security include critical threats to vital national and international support systems, such as the economy, energy and the environment. In this context, the increasing reliance on hydrocarbons has created energy, environmental and economic insecurity.

The concept of energy security is based on three pillars.[18] The first seeks to limit energy vulnerability by reducing dependence on oil use from unstable parts of the world.[19] The second attempts to offer access to adequate supplies at reasonable prices.[20] The third endeavors to prevent international sabotage of oil pipelines and cables, tankers, offshore and onshore installations.[21] Some of these are of particular relevance to this article.

Because the demand for oil and gas far exceeds the supply of those countries that rely most heavily upon them, these countries are compelled to import oil and gas from politically volatile parts of the world. For example, the Middle East, which contains half of the world's remaining conventional oil reserves, is projected to meet almost two-thirds of the increase in global oil demand between 2003 and 2030.[22] The International Energy Agency (IEA) reports that through the year 2010, nearly 80 percent of the expected increase in the world's demand for oil is likely to be supplied by Kuwait, Iran, Iraq, Saudi Arabia, the United Arab Emirate, and the Caspian Region, leaving Venezuela as the only major, low-cost, non-Middle Eastern petroleum producer.[23] According to an assessment by the Center for Strategic and International Studies, by 2020, half of the world's oil demand will be met from countries that have a high risk of internal instability.[24]

This phenomenon exposes many developed countries, including the United States, the European Union, and Japan, to

18 ENERGY SECURITY: MANAGING RISK IN A DYNAMIC LEGAL AND REGULATORY ENVIRONMENT 17-28 (Barry Barton et al. eds., 2004).

19 *Id.*

20 *Id.*

21 *Id.*

22 INTERNATIONAL ENERGY AGENCY, WORLD ENERGY INVESTMENT OUTLOOK 30 (2003).

23 CENTER FOR STRATEGIC AND INTERNATIONAL STUDIES (CSIS), EXECUTIVE SUMMARY: THE GEOPOLITICS OF ENERGY INTO THE 21ST CENTURY – REPORT OF THE CSIS STRATEGIC ENERGY INITIATIVE (2000), *available at* http://www.csis.org/sei/geopoliticsexecsum.pdf (last visited May 1, 2005).

24 *Id.*

shortages of vital energy sources and threats to national security. According to the present U.S. administration, this country faces the most serious energy shortage since the oil embargoes of the 1970s.[25] Estimates indicate that over the next 20 years, U.S. oil consumption will increase by 33 percent, natural gas consumption by as much as 50 percent, and demand for electricity will rise by 45 percent.[26] The implications of such increases in energy consumption are ominous.

Fifth, even taking into consideration the 1974 Agreement on an International Energy Program (IEP),[27] the 1992 United Nations Framework Convention on Climate Change (UNFCCC),[28] and the Energy Charter Treaty of 1994 (ECT),[29] all three of which are discussed further in Section IV, the global response to the world's energy crisis has been unsatisfactory. In 1997, the Kyoto Protocol attempted to address the danger of global warming by requiring reductions of carbon dioxide emissions. Unfortunately, Kyoto almost totally disregarded the need to find alternative sources of energy to supply the burgeoning energy needs of the world. Thus, even Parties to Kyoto recognized the absence of suitable energy options and, as a result, balked at cutting down on usage of coal.

The sidelining of Kyoto, this article argues, has been foreshadowed by an emerging consensus in the scientific community that the reports of the Intergovernmental Panel on Climate Change (IPCC) significantly overestimated the extent and availability of alternative sources of primary energy that

25 While experts disagree as to precisely when world oil production will peak, they are in general agreement that sooner or later this peak will occur. Estimates range from 2004 to 2112 with a median estimate of about 2037. The timing debate is essentially a dispute over the size of the world's endowment of recoverable oil, i.e., an amount consisting of global cumulative production, remaining reserves, reserve growth and undiscovered resources. THE ARLINGTON INSTITUTE, STRATEGY: MOVING AMERICAN AWAY FROM OIL 29 (2003), *available at* http://www.arlingtoninstitute.org/library/A%20Strategy%20-%20Moving%20America%20Away%20from%20Oil.pdf (last visited May. 1, 2005). In a probabilistic assessment study released in 2000, the U.S. Geologic Survey (USGS) estimated this endowment at approximately 3 trillion barrels of oil. On flip side of the debate, experts who disagree with this estimate generally posit the amount as being much closer to 2 trillion barrels. *Id.* To meet projected growth in the world's oil demand, worldwide refining capacity is expected to increase about 60 percent by 2025. AEO 2005, *supra* note 7, at 44.

26 *See* NATIONAL ENERGY DEVELOPMENT GROUP, NATIONAL ENERGY POLICY 9 (May 2001), *at* http://www.whitehouse.gov/energy/National-Energy-Policy.pdf.

27 Agreement on the International Energy Program, Nov. 18, 1974, *available at* http://www.iea.org/Textbase/about/IEP.PDF.

28 United Nations Framework Convention on Climate Change, UNCED, May 9, 1992, S. Treaty Doc. No. 102-38, *reprinted in* 31 I.L.M. 849, *available at* http://unfccc.int/resource/docs/convkp/conveng.pdf.

29 The Energy Charter Treaty, Dec. 17, 1994, 34 I.L.M. 360, *available at* http://www.encharter.org/upload/9/12052067451575115819204971474353213193519086 0213f2543v3.pdf

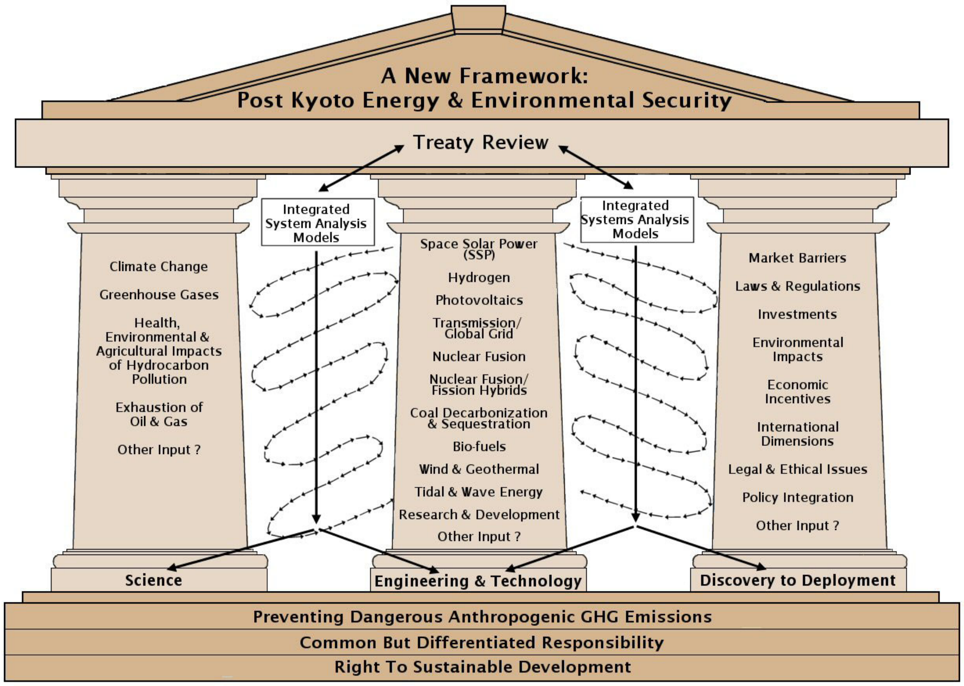
could fill the energy gap created by reductions in the use of coal and other hydrocarbons.[30] Russia's recent decision to ratify Kyoto may breathe some life into the agreement, but does not alter the fact that Kyoto fails to address the world's looming energy deficit by identifying and developing new sources of energy.

Sixth, the search for "smart energy" that is plentiful, efficient, and accessible enough to replace or supplement our present environmentally-damaging fossil fuel sources will involve new technological developments and creative assumptive frameworks, dealing inter alia with energy production, distribution, delivery, storage, conversion, end uses, and environmental protection. These technologies and assumptive frameworks need to be assessed and expressed in a manner that facilitates and secures global, national, and multinational corporate responses.

III. A PRELIMINARY CONCEPTUAL STRUCTURE

The relevance and appeal of any international instrument, and the extent of its acceptance, will depend in great measure on the strength of its scientific, engineering, technological, legal, social, economic and behavioral knowledge base and underlying analysis. For example, the instruments discussed in this paper must be multidimensional, and will require specific expertise, and entail diverse forms of analysis. Thereafter, the varying analytical strands, which are based on fragmented knowledge blocks dealing with science, technology, markets and deployment, will need to be integrated and configured into a sociopolitical aesthetic that lends itself to treaty-making. However, this kind of comprehensive analysis will involve a dynamic interactive process. The framework below, conceptualized as a Greek temple, is a preliminary attempt to provide a schematic of this process.

30 NUTSHELL, *supra* note 4, at 132.



The questions presented in the Doric columns of the figure must be critically evaluated by a broad spectrum of contributors and collaborators, including natural and physical scientists, social scientists, engineers, economists, philosophers and lawyers. These experts must evaluate the various subjects enumerated in the three columns, and such an effort must entail a dynamic and continuous assessment process for analyzing and exploring each column's components. This article will highlight seven facets of this undertaking in the following order: Foundations and Science (column 1) will deal with first and second facets, Engineering and Market Solutions (column 2) will cover the third, fourth and fifth facets, while Discovery to Deployment (column 3) will canvas the sixth and seventh facets.

A. Foundations and Science (Column 1)

First, there is a need for fundamental scientific research on a number of questions referred to in Column 1. Among the most important are those relating to the behavior and feedback of water vapor, clouds and their interaction with radiation, the importance of the stratosphere in the climate change system, and the ocean.[31] Uncertainties still exist about narrow and broad currents along coastlines. Moreover, many changes affecting climate occur within the individual components of the climate system, e.g., atmosphere, ocean, cryosphere and land surface. These changes are compounded by the coupling and interface of two components of the climate system such as the atmosphere and the oceans.

Second, any such assessment must include the possible climatic perils posed by various GHGs; the health, environmental, and agricultural impacts of hydrocarbons; and projections concerning (1) the finite nature of geologic reserves of oil and gas, and (2) how long these particular hydrocarbons may last in the face of increasing world demand. There is an abundance of scientific writing discussing the environmental pollution caused by a range of activities from mining to the final disposal of fossil fuels, and an even greater mass of literature dealing with global warming and climate change. Natural, physical and atmospheric scientists can collaborate with distinguished research institutions and laboratories to synthesize and summarize these scientific findings.

B. Engineering Solutions & Markets (Column 2)

Third, this endeavor must include a ***Technical Review*** of potential engineering solutions, either established or in progress, addressing the various elements in Column 2.

1. Hydrogen

Hydrogen (H_2) holds promise as an ultra-clean, environmentally-friendly, and secure energy option for the world's energy future. Hydrogen can fuel pollution-free internal combustion engines, thereby reducing auto emissions by more than 99 percent. The U.S has focused on developing Hydrogen production, infrastructure, and fuel cell technologies for vehicles that could eliminate America's dependence on oil. In addition, Hydrogen could have broader use as a fuel of the future through stationary power generation and portable power systems, which could be used in consumer electronics.

The Draft Strategic Plan (DSP) of the U.S. Department of Energy (DOE) cogently argues and concludes that the challenge posed by energy insecurity should be addressed by the development of technologies that foster a diverse supply of

31 *See, e.g.*, IPCC, THIRD ASSESSMENT REPORT: CLIMATE CHANGE 2001: SYNTHESIS REPORT, *at* http://www.ipcc.ch/pub/reports.htm (last visited May 1, 2005).

affordable and environmentally sound energy.[32] Thus, in addition to further research into alternative energy and advanced nuclear technologies, the DSP envisions the creation of technologies that will enhance the efficacy of exploration, development and production processes for domestic oil fields. The DSP has also committed to developing new technologies for the DOE's Integrated Sequestration and Hydrogen Research Initiative (ISHRI). This initiative is a 10-year, $1 billion collaboration between government and industry for the purpose of designing, building, and operating FutureGen, which will be the world's first virtually zero-emission, coal-to-Hydrogen power plant. In addition, FutureGen is intended to serve as an international test facility for advanced carbon sequestration technologies.

Internationally, the U.S. envisions that the International Partnership for the Hydrogen Economy (IPHE) will foster the implementation of cooperative efforts to advance research, development, and deployment of Hydrogen production, storage, transport, and distribution technologies.[33] The IPHE will also enhance collaboration on fuel cell technologies, common codes, and standards for Hydrogen fuel utilization, and will help to coordinate international efforts to develop a global Hydrogen economy. In addition, the IPHE will seek to coordinate its efforts with the IEA's complementary work.

The creation of a Hydrogen economy faces many challenges, and prevailing uncertainties. An array of difficulties on technological, economic and infrastructural fronts could mean that the investments of today may not yield the Hydrogen economy of tomorrow. Although Hydrogen is the most abundant element in the universe, it occurs primarily in compounds on earth. Thus, H_2 needs to be produced from diverse primary sources, including natural gas, coal, nuclear power and renewable resources, e.g., wind and solar. Today, "[p]er unit of heat generated, more CO_2 is produced by making H_2 from fossil fuel than by burning fossil fuel directly."[34] In light of the problems encountered in producing and using it, Hydrogen can emerge as the fuel of the future only if other sources of primary energy, such as renewables or nuclear power, can be harnessed to produce H_2 more efficiently and safely.

32 DEPARTMENT OF ENERGY, DRAFT STRATEGIC PLAN 13 (Aug. 6, 2003), *at* http://strategicplan.doe.gov/Draft%20SP.pdf [hereinafter STRATEGIC PLAN].

33 *See* DOE, REVISED DRAFT: TERMS OF REFERENCE FOR THE INTERNATIONAL PARTNERSHIP FOR THE HYDROGEN ECONOMY (2003), *at* http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/rev_terms_ref_iphe.pdf (last visited May 1, 2005).

34 Hoffert, *supra* note 6, at 983.

In contrast to an answer based on Hydrogen alone, producing more primary energy offers a win-win solution to the energy and environmental problems of the world. Finding better sources of primary energy will enable us to replace hydrocarbons regardless of whether we do so through Hydrogen. Consequently, it is necessary to explore the extent and feasibility of producing or harnessing more primary sources of energy, such as solar, wind, ocean thermal, geothermal, tidal power, de-carbonized coal, nuclear fission, fusion and other hybrid technologies, which could replace hydrocarbons and perhaps, though not necessarily, be used to produce Hydrogen.

2. Other Sources of Primary Energy

Despite Hydrogen's possible shortcomings, it is difficult to refute its promise and the desirability of moving to a Hydrogen economy. However, the idea of producing more primary energy based on renewable sources, as well as "new traditionals," e.g., hydrocarbons stripped of their defects, offers a better transitional, as well as final, outcome to the energy crisis. As a transitional strategy, finding new sources of energy will ease the move to a Hydrogen economy. As a final outcome, new sources of energy will always be required to create Hydrogen. Consequently, the development of new sources of primary energy will ultimately enable us to replace hydrocarbons while simultaneously moving toward a Hydrogen economy.

In addition to evaluating the feasibility of producing Hydrogen through such renewable energy sources as solar, wind, ocean thermal, geothermal, tidal power and biofuels, any complete assessment must also canvass technologies that have the potential to facilitate an optimal Hydrogen economy transition by significantly contributing to the availability and utilization of primary energy sources. Candidate technologies referred to in the diagram above include solar space power, de-carbonization and sequestration of carbon dioxide from fossil fuels, nuclear fission, nuclear fusion, and fission-fusion hybrids. This aspect of the study must also traverse Hydrogen production, storage and transport, superconducting electric grids, and energy conservation and efficiency.

For example, in examining solar space power, the ***Technical Review*** should assess the feasibility and strategic efficacy of utilizing space-based geo-engineering and wireless power transmission to capitalize on the unique attributes of space in order to provide energy on Earth. Of particular importance to the geopolitics of energy is the possibility of using satellites to beam solar energy to developing equatorial countries that might otherwise rely on fossil fuels. In addition, a comprehensive analysis of energy options conducive to the attainment of a Hydrogen economy requires the examination of the potential for producing Hydrogen with both nuclear fission and fusion. Such an analysis must also explore technologies and techniques capable of mitigating the adverse environmental impacts of fossil fuel utilization, and evaluate the extent to which decarbonization and carbon sequestration can effectively remediate these impacts. An assessment must also explore the potential for conservation techniques and efficiency technologies to assist in meeting the energy demands of an increasingly voracious global population.

Fourth, the effort must address the ***Market Barriers***, as distinct from technical hurdles, to deploying technology and attracting investment.[35] Deployment refers to the commercial adoption, market viability, penetration and societal acceptance of renewable energy technologies. Currently, there is a cluster of renewable energy technologies, such as those harnessing wind energy, that are commercially viable. However, there are other technologies, including some referred to in Column 2, which may take many decades to come online. Thus, an assessment should identify present market barriers to the deployment of new renewable energy technologies, including high costs and financial barriers of new technologies, issues of sunk costs, information barriers, transaction costs, price distortions, capital turnover rates, market organization and regulations that make deter or delay operation.

Fifth, any effort must address the extent to which ***Organizational and Technological Infrastructure*** could reduce the time lines from discovery to deployment that can currently take up to six decades. The journey from invention to demonstration projects to commercially viable technologies and services capable of market penetration can be an arduous one. Organizationally, the length of time from discovery to market can be shortened by the extent and efficacy of horizontal networks that weave together R&D, capital, knowledge, products and talent.[36] However, such an endeavor requires the active collaboration of governments, private firms, research institutions, financiers, suppliers and consumers. In addition to other precedents for international collaboration, i.e., those offered

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[35] *See generally* IEA, ENHANCING THE MARKET DEPLOYMENT OF ENERGY TECHNOLOGY: A SURVEY OF EIGHT TECHNOLOGIES 16 (1997), *at* http://www.iea.org/text base/publications/newfreedetail2.asp?F_PUBS_ID=547 (last visited May 1, 2005).

[36] George Gilboy, *The Myth Behind China's Miracle,* 83.4 FOREIGN AFFAIRS 33, 41 (Aug. 2004).

by high-energy physics, nuclear fusion and astronomy, the ISHRI process may provide a model for the sort of public and private collaboration required. One thing is clear: Any large-scale effort must examine these and other collaborative ventures with a view toward drawing up possible road maps to achieve a higher level of organization in getting from discovery to market deployment.

On the technological front, the present hub-and-spoke energy transmission networks that currently form the grid system were designed for central power plants close to users. However, in some cases, renewable energy needs to be conveyed thousands of miles. For example, the winds on the plains of North Dakota could make substantial contributions to the energy needs on either U.S. coast. However, the absence of necessary transmission lines and grids prevents the transfer of wind power from North Dakota to the Pacific or Atlantic Coast.[37]

Moreover, while cost-effective photovoltaics and wind turbines, which may serve as catalysts for Hydrogen production, may be expected to come online in the foreseeable future, they presently face formidable transmission problems due to their intermittent and dispersed character. It has been suggested that an advanced global electric grid is a possible alternative to conventional power distribution systems.[38] Consequently, national grid systems may need to be re-engineered, particularly as there is currently no global grid system that could ensure worldwide distribution of photovoltaic, wind, or space solar power. Therefore, any assessment must examine the feasibility of re-engineering national and international grids.

C. Discovery to Deployment (Column 3)

The third column depicted in the above schematic calls for a multi-tiered analysis of the legal, sociopolitical and economic challenges of achieving a sustainable global energy future. As already stated, any such analysis must explicitly recognize and incorporate the need for economic strategies, incentives and modalities for promoting both government and private investment in developing the S&T necessary to make progress toward a clean energy future. This aspect of the project must also address the attendant questions of technology transfer and property rights. While the concept of sustainable development will provide the initial framework for dealing with these issues, it will be necessary to formulate a functional definition of sustainable development, i.e., as it relates to both energy and

37 VACLAV SMIL, ENERGY AT THE CROSSROADS 277–78 (2003).
38 *Id*. at 984.

environmental security. The proffered definition of SD should also lend more specificity to the three interconnected foundational obligations established by the UNFCCC, which are discussed below in Section V(D).

Sixth among the factors enumerated above, is the fact that the technical and economic barriers to the deployment of renewable energy technologies are heavily influenced by governmental decision-making. In fact, governmental regulation dealing with economic incentives, taxes, charges, subsidies, licensing, R&D, conservation and environmental regulations could encourage or discourage the use of renewable energy. Thus, any assessment must identify government regulations that have successfully encouraged market deployment of renewable energy technologies.

Seventh, although R&D policies are referred to in column 2 and subsumed under Governmental Regulations in column 3, the importance of R&D merits discussion on its own merits. The required investment in R&D for the technologies referred to in Column 2, especially space solar power, fission, and Hydrogen, will reach billions of dollars. Technologies accelerated by government research, such as gas turbines, commercial aircraft, spaceflight, radar, lasers, integrated circuits, satellite telecommunications, personal computers, fiber optics and cell phones, took less than multiple decades to move from invention to markets.[39] Currently, however, almost all energy technologies are developed and sold by corporations in the private sector. Thus, while there is little doubt that government-sponsored basic science and technology research is vital,[40] it is equally important to recognize the critical role of private capital and research. In looking at the interplay between the public and private sectors, difficult questions persist about the extent, stage, character and form of focused government R&D expenditures, and how they might be synthesized with private research.

IV. REMAINING QUESTIONS

The foregoing offers a preliminary evaluation – the final picture will emerge only after an integrated policy analysis and assessment is performed. The final stage of such a project will paint a comprehensive account of the scientific, technological, economic, engineering and socio-legal contours of potential primary energy sources, i.e., those that can be used to facilitate

39 Martin I. Hoffert et al., *Response*, 300 SCIENCE 581 (2003) (responding to Brian O'Neill et al., *Letter to the Editor*, 300 SCIENCE 581 (2003)) [hereinafter *Response*].

40 *See id.*

the development of a non-hydrocarbon, and possibly even a Hydrogen, economy. It is at that point that an interdisciplinary assessment, pursued within an integrated and interdisciplinary framework that spans the physical, chemical, biological, social and political sciences, as well as economics, engineering and the law. Such an analysis should focus on the identification and analysis of general and specific solutions to the broad array of issues and problems implicated by transition scenarios.[41] Overall, the assessment will have to include an evaluation of the strengths, weaknesses, costs, and environmental impacts implicated by such transition scenarios, and offer informed conclusions on the extent to which renewable or other energy options are capable – or incapable – of adequately meeting the Hydrogen challenge.

V. LEGAL FOUNDATIONS & TREATY REVIEW[42]

Numerous questions still abound. One such question is: Who will sponsor these instruments? Other questions pertain to the number of countries involved as well the subject matter. The prospect of negotiating a global treaty in law-making assemblies that include almost all nations of the world, such as a Conference of the Parties under UNFCCC or a freestanding framework convention on energy, seems bleak. Comprehensive global agreements are notoriously difficult to negotiate and implement. It may be more feasible to consider drafting a targeted yet limited and functional instrument that includes Organization for Economic Cooperation and Development (OECD) countries as well as stakeholder developing countries such as China and India. Science and technology as well as trade and investment agreements may be the easiest from a negotiating standpoint, but run the risk of fragmenting the necessary global response.

It is perfectly conceivable that targeted pragmatism may prevail over comprehensive idealism. Consequently, an ambitious protocol encompassing all sources of energy may prove too complex. Rather, it is more likely that consensus may form around a more narrowly tailored protocol that, for example, focuses only on de-carbonization and sequestration, space solar power, or fission-fusion hybrid technologies. One such instrument is the United Nations Statute establishing the

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41 *See generally* DOE, A NATIONAL VISION OF AMERICA'S TRANSITION TO A HYDROGEN ECONOMY (2002); DOE, NATIONAL HYDROGEN ENERGY ROADMAP (2002), *at* http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/vision_doc.pdf (last visited May 2, 2005).

42 The following section is a description of the work undertaken by the Energy Environmental Security Initiative (EESI) of the University of Colorado at Boulder.

International Atomic Energy Agency (IAEA), which is a precedent-setting treaty dealing with only one source of energy: civilian nuclear power.[43] Numerous treaties addressing differing aspects of nuclear power have been negotiated under the aegis of the IAEA.[44] In addition, the U.S. recently created an International Partnership for the Hydrogen Economy (IPHE), which is comprised of 15 countries, including the European Union and India, and will focus on the advancement of Hydrogen R&D.[45] Clearly, the particular content and scope of a proposed draft energy instrument will depend on unfolding scientific, technological and geopolitical developments.

A. Rationale for Treaty Review

The task of facilitating the design and negotiation of new instruments is better undertaken when such instruments can be examined against the backdrop, and integrated with, prior international endeavors. Doing so will offer opportunities for building upon strengths while avoiding weaknesses of the existing treaty overlay. The University of Colorado's Energy Environmental Security Initiative (EESI) has chosen to begin the treaty-review process by undertaking a crosscutting ***Sustainable Energy Treaty Analysis*** **(SETA)**, which offers an overview of EESI's research agenda, while simultaneously crafting the project 's legal foundation.

The challenges caused by renewable energy have been addressed, with varying success, in a variety of ways by countries throughout the world. Researching the individual responses of each country to determine how each nation responded is a Sisyphean task. A number of these problems, nonetheless, are common to many nations of the world who have recognized their inability to solve them purely by their own endeavors. This realization has led them into cooperative international agreements addressing these issues. Such international agreements distil and re-state the thinking of the parties, while revealing how different countries have responded to common problems. A study of treaties, therefore, becomes a pathway for garnering the world's common understanding and perception of the energy crisis, and the attendant global responses.

43 Agreement Governing the Relationship Between the United Nations and the International Atomic Energy Agency, G.A. Res. 1145, U.N. GAOR, 12th Sess., at 55 (1957).

44 For more information on the IAEA, see http://www.iaea.org (last visited May 1, 2005).

45 For more information on the IPHE, see http://www.iphe.net/ (last visited May 1, 2005).

International Environmental Law (IEL) offers a compelling analogy. A review of the environmental laws of the various nations comprising the international community reveals the extent to which environmental problems – whether arising from air and water pollution, land use, or exploitation – are omnipresent. In large part, this is because the laws of nature can give rise to identical biophysical reactions. For example, if the receiving medium is the same, then the discharge of waste or residuals, whether in Los Angeles, Liverpool, Düsseldorf or Auckland, will lead to pollution, i.e., because common biophysical reactions take place regardless of where in the world the environment is abused. Likewise, polychlorinated biphenyls act to cause cancer in West Virginia in the same way as they do in Newcastle upon Tyne, UK or Colombo, Sri Lanka.

In addressing these common problems, nation states have often arrived at common regulatory patterns of control. In large part, this is because national boundaries do not serve as biophysical or chemical boundaries. Perhaps more significantly, national boundaries do not serve as biophysical or chemical boundaries. Rather, pollution sometimes migrates from one area to another, thereby causing transboundary legal problems that fall within the province of international, not national, law. The customary IEL principle prohibiting a state from using its property to injure that of another responds to this phenomena, reflects the climate of world opinion, and symbolizes the confluence of national and international law. This principle is restated in numerous declarations and treaties founded upon a universal appreciation of the need to control damage caused by pollution. These articulations recognize a principle, rooted as much in national law as in international comity that has become part of the common law of humankind.

There are a range of international instruments that deal with renewable energy and address R&D, T&I, S&T, energy efficiency, energy conservation, energy transit, technology transfer and energy markets. As part of its comprehensive ***Treaty Review***, EESI will examine all such relevant energy treaties and instruments, although apart from the IEP and the ECT, most of the other agreements are piecemeal efforts designed to deal with discrete questions on a case-by-case basis. In addition, the ***Treaty Review*** will examine a range of related and analogous international (government to government); transnational (private agreements crossing national boundaries); and corporate efforts addressing renewable energy, high energy physics, fusion, and space exploration to determine the most effective and efficient forms of international cooperation.

EESI researchers will analyze the information yielded by the ***Treaty Review*** with a view toward developing an integrated analytical map, which depicts the existing overlay of engineering, geopolitical, socioeconomic, environmental and commercial responses embodied in treaties. This map will be superimposed upon the conceptual vision of EESI in order to provide a cartography of energy challenges and responses. In addition, EESI will also attempt to distil the objectives, principles, cooperative frameworks, institutional structures and dispute settlement mechanisms that might be relevant to the creation of new, and more comprehensive, instruments addressing renewable energy.

The world will be divided into hubs-and-spokes, i.e., with the ***Treaty Review*** organized around the following geographic hubs: (1) United States; (2) International Energy Agency (IEA); (3) European Union (EU); (4) China; and (5) India.

B. Why Begin With The United States?

There are a number of reasons for beginning a treaty review with the U.S. First, from a geopolitical standpoint, the U.S. is the only superpower in the world and has always played a dominant role in forging agreements addressing different facets of energy security. In fact, within the last 40 years, the United States has entered into nearly 350 energy agreements, as well as over 500 agreements dealing with atomic energy.

The U.S. was instrumental in setting up the IEP, which was a response to the energy crisis of 1973–74 when the Arab oil embargo sent oil prices spiraling upward and left the major industrialized countries feeling very vulnerable. Led by the U.S., the rich industrial countries of the world, who were members of the OECD, responded with the IEP, which was a new international treaty aimed primarily at ensuring an adequate supply of oil at an affordable price, and created a new international organization, the IEA, as its implementing agency. More recently, the U.S. has renewed its commitment toward global leadership by hosting the inaugural meeting of the IPHE.[46]

Second, the U.S. recognizes the nature of the energy insecurity confronting the world and is committed to addressing

46 Fact Sheet, U.S. Department of Energy, International Partnership for the Hydrogen Economy (IPHE) (Nov. 25, 2003), *at* http://www.state.gov/g/oes/rls/fs/2003/25983.htm; *see also* DEPARTMENT OF ENERGY: TERMS OF REFERENCE FOR THE INTERNATIONAL PARTNERSHIP FOR THE HYDROGEN ECONOMY (2003), *at* http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/rev_terms_ref_iphe.pdf (last updated Oct. 31, 2003).

it. The DOE is principally a national security agency and this core objective governs all its other activities. Thus, safeguarding energy security lies at the heart of its mission.[47] As previously stated, in the United States, demand for oil is projected to increase by nearly 50 percent by 2025. Petroleum imports already supply more than 55 percent of U.S. domestic needs, and those imports are projected to increase to more than 68 percent by 2025. Because this growing dependence on foreign sources of energy threatens our national security,[48] it is important to understand how the U.S. has addressed the international ramifications of energy security in the past.

Third, between 1974 and 2004, the U.S. entered into hundreds of energy treaties where, for a variety of reasons, the energy challenge called for U.S cooperation with other countries. The EESI ***Treaty Review*** of this large corpus of U.S. energy treaties is facilitated by the treaties' availability and accessibility. In the initial research phase for this project, EESI will identify and analyze all bilateral and multilateral international energy agreements to which the U.S. is a party or active participant.

C. Organizational Structure

Formal U.S. treaties can be identified using the State Department's Treaties in Force. In addition, there are a number of search engines, such as HeinOnline, Westlaw, LexisNexis and Oceana, that can be used to identify U.S. international energy treaties. Executive agreements, however, are also a particularly fertile area for this type of research. While executive agreements are not considered treaties under U.S. law, in some situations, they are nevertheless construed as binding international agreements. Thus, the research for this project will not only need to identify and analyze formal U.S. energy treaties, but also two categories of executive agreements: (1) those that are considered binding international treaties under international law; and (2) informal agreements and general memorandums of understanding, which are a species of international contract. This type of study will help draw a baseline from which the next steps and the new contours of U.S. energy policy may be drawn.

Using a variety of print and online reference sources, EESI has preliminarily identified approximately 500 U.S. treaties dealing with atomic energy. The search of primary U.S. treaty

47 STRATEGIC PLAN, *supra* note 32, at 5.

48 DEPARTMENT OF ENERGY, HYDROGEN POSTURE PLAN 3 (Feb. 2004), *at* http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/hydrogen_posture_plan.pdf.

sources, however, is not yet complete. Therefore, it is entirely possible that the number of U.S. atomic energy treaties identified will exceed 600. With respect to other types of U.S. international energy agreements, EESI has identified 340 U.S. treaties dealing with energy, and the identification of non-atomic U.S. international energy agreements is still continuing. Additionally, research has yet to begin on congressional-executive agreements and sole executive agreements. Thus, the preliminary analysis of the identified agreements has only partially begun.

Given the considerable amount of information this database seeks to encompass, it is essential to organize the identified agreements into pre-established typologies. For instance, U.S. agreements will be categorized according to their legal status, e.g., U.S. treaty (as defined under U.S. law); congressional-executive agreements; and executive agreements. Additionally, each of these agreements will need to be categorized according to subject matter, e.g., renewable energy (and all appropriate sub-categories); nuclear fission; fossil fuels (and all appropriate sub-categories). Each agreement will also be grouped according to its general purpose, e.g., S&T Agreements; R&D Agreements; commercial agreements.

Certain categories, such as purpose or subject matter, will need to work in conjunction with a relevancy hierarchy. For instance, an international agreement may be "primarily," "substantially," or "nominally" relevant to the subject-matter category of "natural gas." Thus, in addition to identifying international energy agreements, EESI's research will also need to cover a preliminary analysis of each identified agreements in order to assign predetermined "signals" to the overall agreement and various parts of the text. This will enable the database to be fully searchable using a variety of field combinations.

Following such identification and categorization, EESI will evaluate each treaty's relevance to energy and environmental security and embark upon a comprehensive analysis of the treaty's implementing machinery, the extent to which implementation has been carried out, and any tangible results achieved, as well as the implications of those results. EESI will use this information to build a freely accessible, online database, which will expand into a truly global undertaking. The database will assist researchers in understanding (1) the impact of these agreements (and their attendant organizations) on key domestic and international policy issues, such as the environment, the economy, and energy security; and (2) the extent to which these agreements can be used to facilitate progress toward a sustainable global energy future.

Moreover, such a database program, using Geographic Information System (GIS) software to display information in a variety of formats, will have considerable pedagogical value. GIS will enable the information to be accessed and combined with other sources, thereby catering to a spectrum of differing user needs. Simply put, researchers could use this program to visually depict different types of energy agreements between countries, as well as international blocs, and to display other attributes, e.g., levels and types of implementation. In addition, this type of program would be a very effective method for teaching undergraduate and graduate students about the role and efficacy of international energy agreements.

This project will enhance the understanding of the efficacy of international energy agreements in achieving their stated goals, and enable the formulations of an integrated analytical map of the technological, geopolitical, socioeconomic, environmental and commercial responses embodied in these agreements. The database will also further sharpen an appreciation of how to utilize and configure international energy agreements in order to help facilitate progress toward a sustainable global energy future.

The comprehensive informational database created by EESI will enhance the knowledge and understanding of key U.S. and international legal and policy questions relating to natural resources, energy and the environment. Sources of energy are critical natural resources, which impact a host of U.S. and international issues relating to economic growth, energy security and sustainable development. Thus, a systematic assessment of international energy agreements entered into by the U.S. will 1) illuminate how America and its treaty partners deal with common challenges; 2) how the parties have succeeded or failed to address various problems; and 3) disclose how America's treaties interface with the existing U.S. statutory and regulatory energy provisions. In addition, specific treaties may provide models for new agreements and suggest an optimal manner of implementation.

D. Foundational Treaties

Three existing treaties are of particular importance: the IEP and the UNFCCC, to which the United States is a Party, and the ECT. Ensuring the stability and security of oil supplies remains the primary objective of the IEA, although its mission is supplemented by a number of environmentally significant long-term objectives pertaining to the conservation of energy, the development of alternative sources of energy, and the R&D of renewable energy. In fact, the latter objectives have assumed great practical importance, and have led the IEA to create a number of Standing Groups and Working Parties dealing with different aspects of the energy-environmental interface. The IEA has also facilitated a host of Implementing Agreements on a variety of renewable energy frontiers, including advanced fuel cells, photovoltaic power systems, Hydrogen, and wind turbine systems.

Internationally, the IEA has become the primary functional engine for facilitating renewable energy research. However, the operational significance attached by the IEA to renewable energy does not arise from legally binding obligations, i.e., the IEP does not contain any legal requirements regarding the creation, transmission and deployment of renewable energy to address the current energy and environmental insecurity. Rather, the renewable energy aims of the IEP are hortatory, not mandatory, and remain secondary to the treaty's primary objective.

In addition, the IEA is essentially comprised of rich developed nations, and does not include developing countries, such as China and India, which, by 2015, will emit more carbon dioxide than the combined emissions of IEP Parties. Moreover, while the IEA has sought to include some developing countries in its Implementing Agreements, such developing countries remain invitees, not peers, and lack parity of status with IEP members. Therefore, new international instruments, which include developing countries as primary parties and stakeholders, could (1) offer better vehicles for fulfilling the work begun by the IEA, and (2) more sharply clarify and define the rather vague and amorphous renewable energy mandates of the IEP, as well as rendering them more specific and enforceable.

The ECT, which came into force in 1998, has sought to provide a non-discriminatory legal foundation for international energy cooperation by facilitating agreements dealing with investment protection, trade in energy, freedom of energy transit, and improvements in energy efficiency. The ECT has been ratified by nearly fifty nations comprised primarily of countries in old and new Europe and the now independent countries of the ex-Soviet Union. The treaty is mainly focused on trade and investment, and provides for the protection of foreign outlay, which helps to ensure a stable basis for cross-border investments among countries with differing social, cultural, economic and legal backgrounds.

In 1998, under the ECT's umbrella, the Parties negotiated a Protocol on Energy Efficiency and Related Environmental

Aspects, which provided a platform for cooperation in the development of energy efficiency. However, although the ECT has taken a step toward global energy cooperation, it does not specifically address how to develop primary sources of renewable energy, and the Parties have, thus far, been unable to agree on a Protocol that addresses either renewable energy or the re-engineering of infrastructure. Moreover, the United States, China, India, Japan, and Australia are not Parties to the ECT. Regardless, it is important to carry the momentum of both the IEP and ECT toward the formation of new international agreements, which must include the developing countries that are destined to become the largest users of hydrocarbons.

The UNFCCC is a response to global climate change, and contains a cluster of amorphous legal obligations. It has the unique distinction of having been ratified by all the countries in the world. Three interlocking mandates are of special importance: (i) stabilization of GHGs; (ii) common, but differentiated, responsibility (CBDR); and (iii) the right to sustainable development. First, UNFCCC requires all parties to stabilize GHG concentrations "at a level that would prevent dangerous anthropogenic interference with the climate system" within a time frame consistent with sustainable development.[49] The implications of this obligation are extensive. Coal, oil, and, to a lesser extent, natural gas, are the primary GHGs implicated in climate change, and the obligation to stabilize GHGs requires the Parties to create or find alternative or substitute sources of energy in order to replace potentially dangerous hydrocarbons and facilitate sustainable development.

Second, this obligation is accentuated by the principles of "equity" and CBDR[50] for protecting the climate system. Equity and CBDR require developed countries to shoulder the primary responsibility and take the lead in combating climate change. Therefore, developed countries have accepted the duty to create and share new technologies that use and enable non-climate changing sources of primary energy.

Third, the first two sets of obligations interlock with the idea of institutionalizing the right to sustainable development.[51] The

49 *See* United Nations Framework Convention on Climate Change, May 9, 1992, art. 2, *at* http://www.globelaw.com/Climate/fcc.htm [hereinafter Climate Change].

50 *See id.* art. 3, para. 1.

51 As set forth in the seminal "Brundtland Report," sustainable development is described as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." *Report of the World Commission on Environment and Development*, U.N. GAOR, 42nd Sess., Agenda Item 83(e), at 54, U.N. Doc. A/42/427 (1987). The report further notes that "[i]n essence, sustainable development is a process of change in which the exploitation of resources, the direction of investments,

assertion that the "Parties have a right to . . . promote sustainable development [and] . . . that economic development is essential for adopting measures to address climate change"[52] was an affirmation of the primary theme of the 1992 United Nations Conference on Environment and Development (UNCED). The primacy of sustainable and economic development was resoundingly re-asserted at the 2002 World Summit on Sustainable Development (WSSD).

These three legal obligations require developed countries, independent of their own energy predicament, to strive for a more diversified energy portfolio, and promote sustainable development in the developing world. A commitment to SD requires the developed world to undertake fundamental R&D on new technologies for producing better forms of primary energy, and then to transfer such technologies to developing countries.[53] The creation of new technologies will remove the threat of energy insecurity in developed countries, while the transfer to developing countries will promote sustainable economic and energy growth.

The major issues arising in this context pertain to (1) the existence, availability and practicability of future sources of primary energy; (2) the candidate technologies that offer feasible solutions to the energy and environmental crisis; and (3) the manner and mode in which new energy sources will be deployed. The canvassing of promising new directions in innovative technologies, which are able to exploit a variety of energy sources, will form a vital element of the proposed knowledge base, and help traverse the cobbled passage from invention to commercial deployment.

VI. CONCLUSION

EESI's research agenda, which is presented above, builds upon research frameworks already delineated[54] that are fostering the development of low GHG global energy systems primarily by facilitating technology research. The present article complements

the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations." *Id*. at 57.

52 *See supra* note 49, art. 3, para. 4.

53 *See id*. art. 4, para. 5. The treaty commits developed country Parties to "take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention." *See generally* Climate Change, *supra* note 49.

54 *See* Franklin M. Orr, *Global Climate & Energy Project (GCEP White Paper)*, *at* http://gcep.stanford.edu/pdfs/gcep_white_paper.pdf (last visited May 1, 2005).

this process by introducing a comprehensive, multi-disciplinary, systems-based policy domain that integrates fragmented scientific, engineering, and policy responses. The primary objective of such a policy domain is to explore ways of institutionalizing and deploying new generation technologies being developed by other more scientifically driven and technologically grounded initiatives. The research identified in this article would provide decision makers with a comprehensive scientific, engineering, economic, and socio-political knowledge base and policy compass that will point toward an integrated approach to the development and deployment of renewable energy through international instruments.