SUSTAINABLE ENERGY: A PRELIMINARY FRAMEWORK

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INTRODUCTION

This symposium issue of the *Indiana Law Review* on *The Law and Economics of Development and Environment* offers an apposite framework for considering sustainable energy and the global interfaces between economic development, energy consumption, and environmental protection. The instant Article argues first that the manner and extent to which increasing global energy demand can be met within the framework of sustainable development (SD), presents the greatest global environmental challenge of the twenty-first century, and second that new energy accords are needed to meet this challenge. The case for new energy accords that address the challenge of sustainable energy is premised upon six widely recognized phenomena.

These six phenomena are: (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 that address this deficit.

This Article will begin by making the case for new energy accords in Part I, followed in Part II by a delineation of a preliminary framework that allows for the entering into of appropriate international agreements. Part III deals with some questions not answered by the preliminary framework. Part IV then describes the need for a comprehensive treaty review that will form the baseline for the negotiation of new international instruments.

I. THE CASE FOR NEW ENERGY TREATIES

First, according to some estimates, today's current primary global power consumption of about twelve terawatts[1] will reach thirty terawatts by 2040.[2]

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1. One terawatt equals 1000 gigawatts or one million megawatts.

2. *See* NEBOJSA NAKICENOVIC ET AL., INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, SPECIAL REPORT ON EMISSION SCENARIOS 95–96, 221 (2000); Martin L. Hoffert et al., *Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet*, 298 SCIENCE 981, 981 (2002) [hereinafter Hoffert et al., *Technology Paths*]; Martin L. Hoffert et al., *Energy Implications of Future Stabilization of Atmospheric CO_2 Content*, 395 NATURE 881, 883 (1998). Future energy scenarios are based on complex demographic, socioeconomic, and technological assumptions and thus may vary significantly.

Other forecasts suggest total global energy consumption will expand by fifty-four percent between 2001 and 2025.[3] A significant and troubling part of this projected increase in energy demand will occur in developing countries that rely primarily upon the combustion of hydrocarbons, such as coal, to produce the electricity necessary to meet their energy demands.

The increasing demands and consumption of energy by developing countries is of particular relevance to this symposium. In 2001, developing nations consumed about sixty-four percent as much oil as the industrialized nations and by 2025 they are expected to consume about ninety-four percent as much oil as the industrialized nations.[4] As a result of the increasing reliance of developing countries on fossil fuels (particularly coal, the most carbon-intensive of fossil fuels) and despite lower projected energy consumption levels than that of the industrialized nations, CO_2 emissions from developing countries will be greater than those of developed countries by 2025.[5]

Currently, the United States emits considerably more CO_2 from burning oil than any other country—e.g., more than Africa and Western Europe combined and 2.7 times as much as India and China combined.[6] The developing countries of Asia are projected to have the strongest energy consumption growth rate, accounting for nearly forty percent of the entire projected increase in world energy consumption through 2025. For developing Asia alone, CO_2 emissions are projected to increase from 6.0 billion metric tons carbon equivalent in 2001 to 11.8 billion metric tons in 2025.[7] During this same period of time, total U.S. CO_2 emissions from energy use are projected to increase from 5.692 to 8.142 billion metric tons carbon equivalent.[8]

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 that 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 public health effects and impacts of acid rain, heavy metals, urban smog (created by the mining and burning of fossil fuels) can be very damaging to both developing and

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3. ENERGY INFO. ADMIN. (EIA), INTERNATIONAL ENERGY OUTLOOK 2004, at 7 (2004), *available at* www.eia.doe.gov/pub/pdf/international/0484(2004).pdf. The EIA's "reference case" projects total world energy consumption will increase from 404 quadrillion British thermal units (Btu) in 2001 to 623 quadrillion Btu in 2025. *Id.* at 7.

4. *Id.* at 3.

5. *Id.* at 7, Table 1: World Energy Consumption and Carbon Dioxide Emissions by Region, 1990–2025.

6. ENERGY INFO. ADMIN., ANNUAL ENERGY OUTLOOK 6–7 (2003) [hereinafter AEO2003]; ENERGY INFO. ADMIN., INTERNATIONAL ENERGY ANNUAL, Table H2: World Carbon Dioxide Emissions from Petroleum Consumption, 1992-2001 (2001).

7. ENERGY INFO. ADMIN., INTERNATIONAL ENERGY OUTLOOK, *supra* note 6, Table A9: World Carbon Dioxide Emissions by Region Reference Case, 1990-2025.

8. *Id.*

developed countries.

Third, oil and gas are finite and non-renewable natural resources. While the finite nature of oil and gas is not in doubt, controversy abounds as to the extent, and the anticipated life span of petroleum reserves.[9] There is sharp disagreement about whether the world faces an imminent prospect of an oil peak followed by an inevitable decline and exhaustion of oil. The advocates of both scarce and plentiful oil scenarios 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*,[10] has been viewed as the most thorough and methodologically modern assessment of world crude oil and natural gas resources ever attempted.

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 that published by Dr. M. King Hubbert of the USGS in 1974.[11] The USGS forecasts are more conservative in that they forecast less resources and reserves than the EIA. It is unnecessary to enter into the fray of this controversy because even the more optimistic conclusions of the EIA[12] are consistent with the thesis of this essay.

According to the EIA, the peaking of oil, which they see happening toward the middle of the century, will in part depend on the rate of demand growth. What is germane to sustainable energy as espoused by this Article is that, according to the EIA, the intensity of demand for petroleum will accelerate and

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9. What is clear is that 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.

10. T.S. AHLBRANDT ET AL., U.S. GEOLOGICAL SURVEY (USGS), U.S. DEP'T OF INTERIOR, WORLD PETROLEUM ASSESSMENT 2000 (2003) (USGS Fact Sheet FS-0622-03) [hereinafter WORLD PETROLEUM ASSESSMENT 2000], *available at* http://www.usgs.gov/fs/fs-062-03. A detailed analysis using the assessment appears in Alfred J. Cavallo, *Predicting the Peak in World Oil Production*, 11 NAT. RESOURCES RES. 187 (2002).

11. John Wood & Gary Long, Long Term World Oil Supply: A Resource Base/Production Path Analysis (July 28, 2000) (unpublished presentation), *available at* http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2000/long_term_supply/index.htm.

12. The EIA concludes that the world production peak for conventionally reservoired crude will be closer to the middle of the twenty-first century than to its beginning. John H. Wood et al., Energy Info. Admin., *Long-Term World Oil Supply Scenarios: The Future Is Neither Bleak or Rosy as Some Assert*, *at* http://www.eia.doe.gov/pub/oil_gas/petroleum/feature_articles/2004/worldoilsupply/oilsupply04.html (posted Aug. 18, 2004). A paper, funded by the Department of Energy's (DOE) Office of Naval Petroleum and Oil Shale Reserves, has not concurred with the projections of the EIA, and supports the thesis of an imminent oil peak. *See* Harry R. Johnson et al., Office of Naval Petroleum and Oil Shale Reserves, DOE, 1 STRATEGIC SIGNIFICANCE OF AMERICA'S OIL SHALE RESOURCES (2004), *available at* http://www.fe.doe.gov/ programs/reserves/Pubs_NPR/npr_strategic_significancev7. pdf.

advance its exhaustion. However, 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.[13] The demand for petroleum will be reduced even more drastically if, as argued in this essay, there is increased reliance on renewable energy.

Fourth is national security. Traditionally, national security has been associated with armed aggression and the ability to thwart military invasions or subversion. More contemporary concepts of national 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, as well as environmental and economic, insecurity.

Because the demand for oil and gas far exceeds the supply within those countries that rely most heavily upon them, these countries are compelled to import oil and gas from politically volatile parts of the world. With half of the world's remaining conventional oil reserves, the Middle East is projected to meet almost two-thirds of the increase in global oil demand between 2003 and 2030.[14] The International Energy Agency (IEA) reports that, through the year 2010, nearly eighty 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—with Venezuela as the only major low-cost, non-Middle East petroleum producer.[15] According to an assessment by the Center for Strategic and International Studies (CSIS), half of the world's oil demand "will be met from countries that pose a high risk of internal instability" by the year 2020.[16]

This phenomenon exposes many developed countries to shortages of vital energy sources. Indeed, energy shortages are perceived as posing a threat to the national security of the United States, the European Union, Japan, and other developed nations. According to the present U.S. administration, this country "faces the most serious energy shortage since the oil embargoes of the 1970s."[17]

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13. Wood et al., *supra* note 12.

14. HIROYUKI KATO, INT'L ENERGY AGENCY, WORLD ENERGY INVESTMENT OUTLOOK: 2003 INSIGHTS 30 (2003).

15. CENTER FOR STRATEGIC AND INT'L STUDIES (CSIS), EXECUTIVE SUMMARY: THE GEOPOLITICS OF ENERGY INTO THE 21ST CENTURY—REPORT OF THE CSIS STRATEGIC ENERGY INITIATIVE, at xvi (2000).

16. *Id.* at xvii.

17. NAT'L ENERGY POLICY DEV. GROUP, NATIONAL ENERGY POLICY: REPORT OF THE NATIONAL ENERGY POLICY DEVELOPMENT GROUP viii (2001) [hereinafter NATIONAL ENERGY POLICY]. 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 for world oil peak production range from 2004 to 2112, with a mean estimate of about 2037. The timing debate is essentially a dispute over the size of the world's endowment of recoverable oil—an amount consisting of global cumulative production, remaining reserves, reserve growth, and undiscovered resources. THE

Estimates indicate that over the next twenty years, U.S. oil consumption will increase by thirty-three percent, natural gas consumption by as much as fifty percent, and demand for electricity will rise by forty-five percent.[18] The implications of such increases in energy consumption are ominous.

Fifth, even appreciating the 1974 Agreement on an International Energy Program (IEP),[19] the 1992 United Nations Framework Convention on Climate Change (UNFCCC),[20] and perhaps the Energy Charter Treaty of 1994 (ECT),[21] the global response to the energy crisis has been unsatisfactory.

In this context, the Kyoto Protocol of 1997 (Kyoto) responds to the danger of global warming caused by anthropogenic actions and requires reductions of carbon dioxide emissions. Unfortunately, Kyoto almost totally disregards the need to find alternative sources of energy that can supply the burgeoning energy needs of the world. Not surprisingly, even parties to Kyoto have recognized the absence of suitable alternatives and balked at cutting down on coal. The sidelining of Kyoto has been foreshadowed by the emerging consensus among 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 could fill the energy gap created by reductions in the use of coal and other hydrocarbons.[22] The recent decision of Russia to ratify Kyoto may breathe some life into it, but does not alter the fact that Kyoto fails to address the looming energy deficit by identifying and developing new sources of energy.

Sixth, the search for smart energy that is plentiful, efficient, and accessible 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,

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ARLINGTON INSTITUTE, A STRATEGY: MOVING AMERICA AWAY FROM OIL 29 (2003), *available at* http://www.arlingtoninstitute.org/library/A%20Strategy%20-%20Moving%20America%20Away%20from%20Oil.pdf. In a probabilistic assessment study released in 2000, the USGS estimated this endowment at approximately three trillion barrels of oil. *See* WORLD PETROLEUM ASSESSMENT 2000, *supra* note 10. On the flip side of the debate, experts who disagree with this estimate generally posit the amount as being much closer to 2 trillion barrels. THE ARLINGTON INSTITUTE, *supra*; *see also* WORLD PETROLEUM ASSESSMENT 2000, *supra* note 10, Table 2. The world's total oil demand is projected to increase from 76.0 million barrels per day in 2001 to 123 million by 2025. To meet this growth in demand, worldwide refining capacity is expected to increase from 81.2 million barrels per day in 2002 to almost 133 million barrels per day by 2025—an expansion of sixty-four percent. AEO2003, *supra* note 6, at 52–54.

18. *See* NATIONAL ENERGY POLICY, *supra* note 17, at x.

19. INT'L ENERGY AGENCY, AGREEMENT ON AN INTERNATIONAL ENERGY PROGRAM 14 I.L.M. 1 (1974), *available at* http://www.iea.org/Textbase/about/IEP.PDF.

20. UNITED NATIONS, UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE 31 I.L.M. 849 (1992), *available* at http://unfccc.int/resource/docs/convkp/conveng.pdf [hereinafter UNFCCC].

21. The Energy Charter Treaty, Dec. 12, 1996, 34 I.L.M. 381. *See* discussion *infra* Part IV.

22. Hoffert et al., *Technology Paths*, *supra* note 2, at 981.

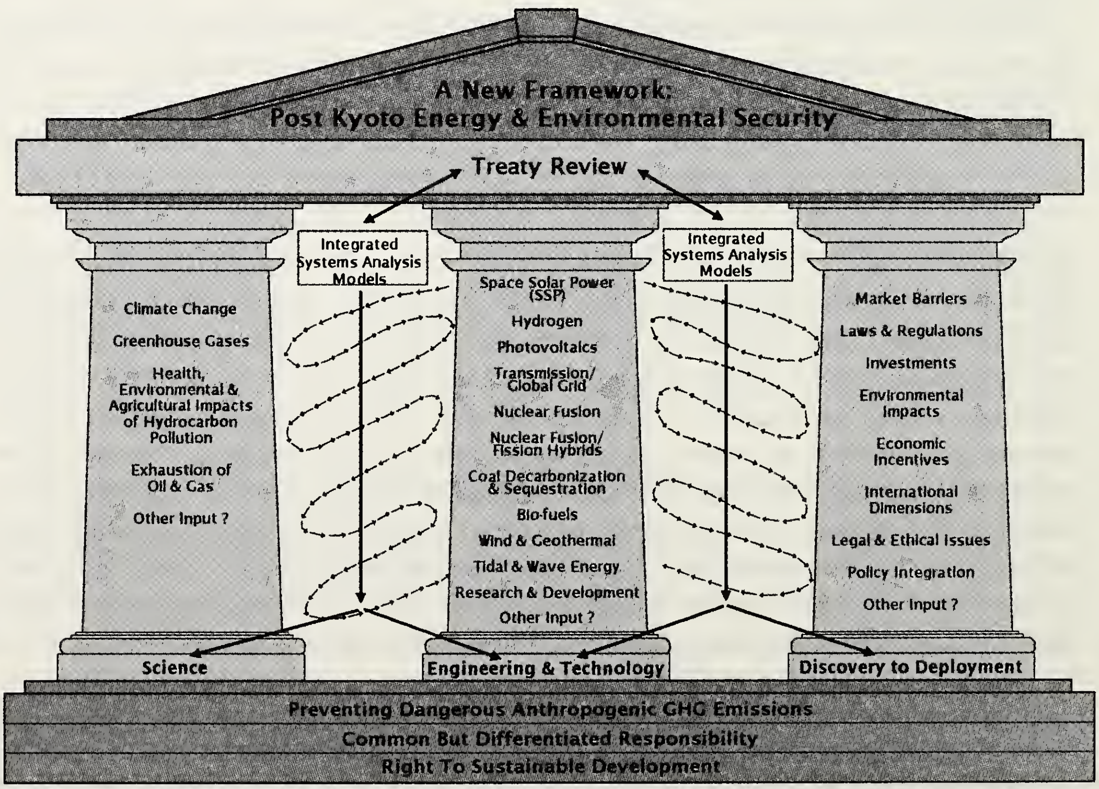
storage, conversion, end uses, and environmental protection. These technologies and assumptive frameworks need to be assessed and expressed in a manner which facilitates and secures global, national, and multinational corporate responses.

II. 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 entities, and each of their facets will require specific expertise and entail diverse forms of analysis. Thereafter, the varying analytical strands 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. This kind of comprehensive analysis will involve a dynamic interactive process.

A preliminary attempt to provide a schematic of this process is conceptualized as a Greek temple.

CONCEPTUALIZED FRAMEWORK



The matters 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. Such an effort must entail a dynamic continuous assessment process for analyzing and exploring the components of the three columns.

A. Foundations and Science [Column One]

First, there is a need for fundamental scientific research on a number of questions referred to in Column One. 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 oceans.[23] Uncertainties still exist about narrow and broad currents along coast lines. Moreover, many changes affecting climate occur within the individual components of the climate system, such as atmosphere, ocean, cryosphere, and land surface. These are compounded when there is coupling between them, for example, the interaction between atmosphere and ocean.

Second, any such assessment must include the possible climatic perils posed by various Green House Gases (GHGs), the health, environmental, and agricultural impacts of hydrocarbons, along with projections regarding both the finite nature of geologic reserves of oil and gas and how long these particular hydrocarbons may last in the face of increasing world demand. There is an abundance of scientific writing dealing with the environmental pollution caused from mining to 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 such scientific findings.

B. Engineering Solutions and Markets [Column Two]

This endeavor must also include a technical review of engineering solutions either established or in progress, referred to in Column Two of the conceptual schematic.

1. Hydrogen.—Hydrogen 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, reducing auto emissions by more than ninety-nine percent. The United States has focused on developing hydrogen production, infrastructure, and fuel cell technologies for vehicles that could eliminate dependence on oil. Apart from transportation applications, hydrogen could have broader use as a fuel of the future through stationary power generation and portable power systems that could be used in consumer

23. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2001: SYNTHESIS REPORT 188-92 (Robert T. Wilson et al. eds., 2001).

electronics.

The recent Draft Strategic Plan (DSP) of the U.S. Department of Energy (DOE) cogently argued and concluded that the challenge posed by energy insecurity should be addressed by developing technologies that foster a diverse supply of affordable and environmentally sound energy.[24] Thus, in addition to further research into alternative energy and advanced nuclear technologies, the DSP envisions developing technologies that will enhance the efficacy of exploration, development, and production processes for domestic oil fields.[25] The DSP also commits to developing new technologies for the DOE's Integrated Sequestration and Hydrogen Research Initiative. This initiative is a ten-year, $1 billion collaboration between government and industry for the purpose of designing, building, and operating FutureGen, the world's first virtually zero-emission, coal-to-hydrogen power plant. FutureGen is also intended to serve as an international test facility for advanced carbon sequestration technologies.

Internationally, the United States 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, delivery[,] and distribution technologies. The IPHE will also enhance collaboration on fuel cell technologies, common codes and standards for hydrogen fuel utilization and safety, and help to coordinate international efforts to develop a global hydrogen economy. The IPHE will seek to coordinate closely with the [IEA], as its work is an important complement to IPHE efforts.[26]

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 is found 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, such as 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 the fossil fuel directly."[27] In light of the problems encountered in producing and using hydrogen, it 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 hydrogen more efficiently and safely.

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24. DOE, STRATEGIC PLAN: PROTECTING NATIONAL, ENERGY, AND ECONOMIC SECURITY WITH ADVANCED SCIENCE AND TECHNOLOGY AND ENSURING ENVIRONMENTAL CLEANUP (DRAFT) 13 (2003), *available at* http://strategicplan.doe.gov/Draft%20SP.pdf.

25. *Id.*

26. DOE, Terms of Reference for the International Partnership for the Hydrogen Economy (Revised Draft) 1 (Oct. 31, 2003), *available at* http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/rev_terms_ref_iphe.pdf.

27. Hoffert et al., *Technology Paths*, *supra* note 2, at 983.

Producing more primary energy offers a better solution to the energy and environmental problems of the world than one based on hydrogen alone. 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, decarbonized coal, nuclear fission, nuclear fusion, and other hybrid technologies that could replace hydrocarbons and perhaps, though not necessarily, be used to produce hydrogen.

2. *Other Sources of Primary Energy.*—Despite possible shortcomings of hydrogen, it is difficult to refute its promise and the desirability of moving to a hydrogen economy. However, producing more primary energy based on renewable sources, as well as "new traditionals" (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. In terms of a final outcome, new sources of energy will always be required to create hydrogen. Consequently, the development of new sources of primary energy will enable us to replace hydrocarbons while simultaneously moving toward a hydrogen economy.

In addition to evaluating the feasibility of producing hydrogen through renewable energy sources, the 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. A number of the candidate technologies referred to in the diagram include solar space power, decarbonization 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 can assess the feasibility and strategic efficacy of utilizing space-based geo-engineering and wireless power transmission to capitalize on the unique attributes of space and 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. Such a prospect may be examined in this aspect of the project.

A comprehensive analysis of energy options conducive to the attainment of a hydrogen economy requires examining 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. In this vein, the assessment must evaluate the extent to which decarbonization and carbon sequestration can effectively remediate these impacts. The assessment will also explore the potential for conservation techniques and efficiency technologies to assist in meeting the energy demands of an increasingly voracious global population.

Third, the effort must address the market barriers (as distinct from technical hurdles) in deploying technology and attracting investment.[28] Deployment refers to the commercial adoption, market viability, penetration, and societal acceptance of renewable energy technologies. There is a cluster of renewable energy technologies such as those harnessing wind energy that are now commercially viable. Others, including some of the new technologies referred to in Column Two, like fusion power reactors, may take many decades to come online. Present market barriers to the deployment of new renewable energy technologies must be identified, including high costs and financial barriers, issues of sunk costs, information barriers, transaction costs, price distortions, capital turnover rates, market organization, and regulations that may deter or delay deployment.

Fourth, this effort must address the extent to which organizational and technological infrastructure could reduce the time lines from discovery to deployment that can take up to six decades. The journey from invention through 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 capital, knowledge, products, and talent.[29] Such an endeavor requires the active collaboration of governments, private firms, research institutions, financiers, suppliers, and consumers. The DOE's Integrated Sequestration and Hydrogen Research Initiative, referred to previously, may pave the way and provide a model for the sort of public and private collaboration required. There are other precedents for international collaboration offered by high-energy physics, nuclear fusion, and astronomy. Any large-scale effort must examine these and other collaborative ventures with a view to drawing up possible road maps for better organizing the process from discovery to market deployment.

On the technological front, the present hub and spoke energy transmission networks that form the grid system were designed for central power plants close to users. That is not the case with renewable energy which needs, in some cases, to be conveyed thousands of miles. For example, in the United States, the winds on the planes 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 presently prevents the transfer of wind power from North Dakota to the Pacific or Atlantic Coast.[30]

Moreover, while cost-effective photovoltaics and wind turbines may be expected to come online in the foreseeable future (and could also serve as catalysts for hydrogen production), 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

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28. INT'L ENERGY AGENCY, ENHANCING THE MARKET DEPLOYMENT OF ENERGY TECHNOLOGY 16 (1997).

29. George F. Gilboy, *The Myth Behind China's Miracle*, 83 FOREIGN AFF. 33, 41 (2004).

30. VACLAV SMIL, ENERGY AT THE CROSSROADS: GLOBAL PERSPECTIVES AND UNCERTAINTIES 277 (2003).

power distribution systems.[31] Consequently, national grid systems may need to be re-engineered. Internationally, there is no global grid system that could ensure world-wide distribution of photovoltaic and wind, as well as, solar space power when available. Such a project must therefore examine the feasibility of re-engineering national and international grids.

C. Discovery to Deployment [Column Three]

The third column depicted in the schematic calls for a multi-tiered analysis of the legal, sociopolitical, and economic challenges of achieving a sustainable global energy future. As noted above, 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 science and technology necessary to making progress toward a clean energy future. This aspect of the project will also address the attendant questions of technology transfer and property rights. While the concept of sustainable development (SD) will provide the initial framework for dealing with these issues, it will be necessary to formulate a functional definition of SD insofar as it relates to energy and environmental security. The proffered definition of SD should also lend more specificity to the three interconnected foundational obligations established by the UNFCCC.

The technical and economic barriers to the deployment of renewable energy technologies are influenced by governmental decision making, and governmental regulation assumes importance. Government regulations dealing with economic incentives, taxes, charges, subsidies, licensing, research and development (R&D), conservation, and environmental regulations could encourage or discourage renewable energy. This effort must identify government regulations that have been successful in encouraging market deployment of renewable energy technologies.

R&D policies are referred to in Column Two and subsumed under Governmental Regulations in Column Three, and the importance of R&D merits special discussion. The required investment in R&D for the technologies referred to in Column Two, especially space solar power, fission, and hydrogen, will run into billions of dollars. Almost all energy technologies are developed and sold by corporations in the private sector. 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.[32] While there is little doubt that government sponsored basic science and technology research is vital,[33] it is equally important

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31. Hoffert et al., *Technology Paths*, *supra* note 2, at 984.

32. Martin L. Hoffert et al., *Response*, 300 SCI. 582, 583 (2003) (letter to the editor) (citing M.I. HOFFERT & S.D. POTTER, ENGINEERING RESPONSE TO GLOBAL CLIMATE CHANGE 205-59 (R.G. Watts ed., 1997)).

33. *Id.*

to recognize the critical role of private capital and private research. Difficult questions persist about the extent, stage, character, and form of focused government R&D expenditures and how they interface and might be synthesized with private research.

III. Remaining Questions

The forgoing offers a preliminary, not final, assessment. The final picture will emerge only after the integrated policy analysis and assessments are 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 that might also be used to facilitate the development of a hydrogen economy.

The interdisciplinary assessment at that point can focus on the identification and analysis of general and specific solutions to the broad array of issues and problems implicated by transition scenarios to a non-hydrocarbon, or even a hydrogen, economy.[34] This focus must be pursued within an integrated and interdisciplinary framework that spans the physical, chemical, biological, social and political sciences, as well as economics, engineering, and law. Overall, the assessment can include an evaluation of the strengths, weaknesses, costs, and environmental impacts implicated by such transition scenarios, and can offer informed conclusions on the extent to which renewable or other energy options are capable—or incapable—of adequately meeting the hydrogen challenge.

Numerous questions still abound. One such question asks who will sponsor these instruments. Other questions pertain to the number of countries involved as well as the subject matter of these instruments. 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 the 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 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 to be too complex. Instead, 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. The statute of the International Atomic Energy Agency (IAEA)[35]

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34. *See generally* DOE, A National Vision of America's Transition to a Hydrogen Economy—to 2030 and Beyond (2002); DOE, National Hydrogen Energy Roadmap (2002).

35. The Statute of the International Atomic Energy Agency, Oct. 26, 1956, 8 T.I.A.S. 3873 (1957).

stands out as a precedent setting treaty that deals with just one source of energy: civilian nuclear power. Numerous treaties addressing differing aspects of nuclear power have been negotiated under the aegis of the IAEA. More recently the United States has created an International Partnership for the Hydrogen Economy (IPHE)[36] with fifteen partners, including the European Commission and India, for advancing Hydrogen R&D. The particular content and scope of the proposed draft energy instrument will depend on unfolding scientific, technological, and geopolitical developments.

IV. Legal Foundations and Treaty Review

A. *Foundational Treaties*

The task of facilitating the design and negotiation of new instruments is better undertaken if it is integrated with prior international endeavors, thus allowing for building upon strengths and avoiding weaknesses of the existing treaty overlay. Two existing treaties are of particular importance: the International Energy Program (IEP) and the UNFCCC. The United States is a party to both agreements.

The IEP 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. The rich industrial countries of the world, who were members of the Organization for Economic Cooperation and Development (OECD), responded with the IEP: a new international treaty aimed primarily at ensuring the adequate supplies of oil at affordable prices. The IEP created a new international organization, the International Energy Agency (IEA), as its implementing agency.

Ensuring the stability and security of oil supplies remains the primary objective of the IEA. This objective is supplemented by a number of environmentally significant long-term objectives pertaining to the conservation of energy, development of alternative sources of energy, and research and development of renewable energy. These environmental objectives have assumed much greater practical importance and 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 created by the IEP. The renewable energy aims of IEP are hortatory, not mandatory, and remain secondary to its primary objective of securing reliable oil supplies. The IEP does not contain any legally binding obligations requiring

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36. International Partnership for the Hydrogen Economy, *at* http://www.iphe.net.

the creation, transmission, or deployment of renewable energy to address today's energy and environmental insecurity. Moreover, it is essentially an organization of rich, developed nations. Its membership does not include developing countries, like China or India, who will become the greatest consumers of fossil fuels, and emit more carbon dioxide in 2015 than the combined emissions of IEP Parties. While the IEA has sought to include some developing countries in its Implementing Agreements, such countries remain invitees rather than peers, and lack parity of status with IEP members. Consequently, new international instruments in which developing countries are primary parties and stakeholders offer better vehicles for fulfilling the work begun by the IEA. Such new instruments could more sharply clarify and define the rather vague and amorphous renewable energy mandates of the IEP, and render them more specific and enforceable.

The Energy Charter Treaty (ECT)[37] was agreed to in 1994 with a view to establishing a legal framework to promote long term cooperation in the energy field. It came into force in 1998, seeks to provide a non-discriminatory legal foundation for international energy cooperation, and deals with investment protection, trade in energy, freedom of energy transit, and improvements in energy efficiency. The ECT has been ratified by nearly fifty countries, primarily in old and new Europe, and the now independent countries of the ex-Soviet Union. It is mainly focused on trade and investment and provides for protection of foreign investment, thus ensuring a stable basis for cross border investments among countries with differing social, cultural, economic, and legal backgrounds. Under its umbrella the parties negotiated a Protocol on Energy Efficiency and Related Environmental Aspects (PEERA) in 1998, which provides a platform for the cooperation in developing energy efficiency.

While 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 been unable to agree on a Protocol dealing with renewable energy or the re-engineering of infrastructure. Moreover, the United States, China, India, Japan, and Australia are not parties to the ETC. It is important to carry the momentum of the IEP and ECT toward international agreements that include developing countries like China and India that will become the largest users of hydrocarbons.

The UNFCCC is a response to global climate change and contains a cluster of amorphous legal obligations.[38] 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 greenhouse gases (GHGs); (ii) common but differentiated responsibility (CBDR); and (iii) the right to sustainable development. First, the 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

37. The Energy Charter Treaty, *supra* note 21.

38. UNFCCC, *supra* note 20.

sustainable development.[39] The implications of this obligation are extensive. Coal, oil, and to a lesser extent natural gas, are the primary source GHGs implicated in climate change, and the obligation to stabilize GHGs requires the parties to create or find alternative or substitute sources of energy to replace potentially dangerous hydrocarbons and facilitate sustainable development.

This obligation is accentuated by the principles of "equity" and CBDR for protecting the climate system.[40] Equity and CBDR require developed countries to shoulder the primary responsibility and take the lead in combating climate change. Developed countries have, therefore, accepted a duty to create and share new technologies that use and enable non-climate changing sources of primary energy.

The first two sets of obligations interlock with a third: institutionalizing the right to sustainable development.[41] The assertion that the "[p]arties have a right to . . . promote sustainable development [and] . . . that economic development is essential for adopting measures to address climate change"[42] 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 recently concluded 2002 World Summit on Sustainable Development.

These three legal obligations require developed countries, independent of their own energy predicament, to strive for a more diversified energy portfolio and place a duty on them to promote sustainable development in the developing world. A commitment to sustainable development requires the developed world to undertake fundamental R&D on new technologies for producing better forms of primary energy and transfer such technologies to developing countries.[43] The creation of new technologies will remove the threat of energy insecurity in developed countries, while their transfer to developing countries will promote sustainable economic and energy growth.

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39. *Id.* at 854, art. 2.

40. *Id.* at 854, art. 3(1).

41. 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: Our Common Future*, U.N. Environment Programme, 42d Sess., Agenda Item 83(c), at 43, 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, 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 46.

42. UNFCCC, *supra* note 20, at 854, art. 3(4).

43. In addition to other relevant provisions of the UNFCCC, Article 4(5) 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." *Id.* at 858, art. 4(5).

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

B. Treaty Review

The legal foundations laid by the treaties discussed above have been supplemented by hundreds of other bilateral and multilateral energy treaties of varying stripes. These treaties need to be analyzed with a view to ascertaining the extent to which energy treaties presently in force, as well as those forming their historical backdrop and context, that were entered into within the last fifty years, inform the legal foundations of the legal analysis.

The challenges facing renewable energy have been addressed with differing success, in a variety of ways, by the 192 countries of the world. Researching the individual responses of each country to determine how each nation responded to the suite of challenges it confronts is a Sisyphean, perhaps impossible, task. A number of these problems, nonetheless, are common to many nations of the world, who ought to have recognized their inability to solve them purely by their own endeavors. This realization should have led them into cooperative international agreements addressing these issues.

Whether they have done so remains to be determined by a comprehensive and legally searching treaty review. When properly analyzed, such international agreements will show how different countries have responded to common problems. They will offer a window to their countries' thinking because, to a considerable degree, treaties or agreements distill, re-state, and reduce the thinking of the parties to writing. A study of treaties thus becomes a felicitous and innovative way of garnering the world's common understanding and perception of the energy crisis and the attendant global responses.

One way of proceeding would be to divide the world into hubs and spokes and undertake a 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. There are a range of international instruments dealing, *inter alia*, with renewable energy, R&D, trade and investment, science and technology, energy efficiency, energy conservation, energy transit, technology transfer, and energy markets.

A credible treaty review must examine all relevant energy treaties. Such an examination will form a valuable baseline from which to assess the future and determine the scope and subject matter of future international energy instruments. At an impressionistic level, it appears that the IEP and the ECT, referred to in Part IV.A, are among the more comprehensive multilateral treaties, while the other agreements are piecemeal efforts to deal with discrete questions on a case by case basis.

Such a treaty review must also 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.[44]

CONCLUSION

The treaty review outlined above constitutes the research agenda of the Energy & Environmental Security Initiative of the University of Colorado (EESI).[45] As previously explained, such an ambitious research venture calls for the construction of a knowledge base and analytical compass that together will facilitate the development and drafting of international energy instruments.

As currently envisioned, the principal objective of new energy 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.[46] The research agenda delineated above seeks to advance the objective of promoting new treaties and other international instruments promoting sustainable energy. It seeks to do so by providing decisionmakers with a comprehensive scientific, engineering, economic, and socio-political knowledge base and policy compass that will illuminate pathways toward an integrated approach to the development and deployment of renewable energy through international instruments.

The research agenda presented in this Article builds upon research frameworks already delineated,[47] which are fostering the development of low greenhouse gas (GHG) global energy systems primarily by facilitating technology research. The present Article complements this process by introducing a comprehensive multi-disciplinary systems-based policy domain that integrates hitherto fragmentary scientific, engineering, and policy responses. The primary objective of such a policy domain will be to explore ways of institutionalizing and deploying new generation technologies being developed by other more scientifically driven and technologically grounded initiatives.

While this Article seeks to advance the negotiation of international accords necessary to meet future energy needs, it does not presume to legislate the scope, structure, specific subject matter, final terms, or norms of the proposed new energy instruments. Instead, it is intended as a starting point from which to begin

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44. Importantly, such a treaty review has been initiated by researchers, including the author, at the University of Colorado at Boulder as part of the Energy & Environmental Security Initiative (EESI). *See* the EESI homepage, *at* http://www.colorado.edu/law/eesi.

45. For a more thorough description, see *id.*

46. The World Energy Council reports primary energy consumption for different countries based on rules for conversion of energy sources into primary energy. This accounting is a suitable method for comparing consumption of different energy sources in different countries.

47. *See* Franklin M. Orr, Jr., Global Climate and Energy Project, Stanford University (n.d.), *available at* http://gcep. stanford.edu/pdfs/gcep_white_paper.pdf.

the arduous interdisciplinary and collaborative work necessary to negotiate instruments ranging from science and technology agreements and Trade and Investment treaties to more ambitious regional treaties and overarching global conventions or protocols.