

INTERNATIONAL RELATIONS AND SECURITY NETWORK

ENERGY AND THE ENVIRONMENT

GLOBAL WARMING AND THE INDUSTRIAL SYSTEM



INTERNATIONAL RELATIONS AND SECURITY NETWORK

ENERGY AND THE ENVIRONMENT

GLOBAL WARMING AND THE INDUSTRIAL SYSTEM

Iddo Wernick





TABLE OF CONTENTS

Politics and Problems	5
The Paradigm of Industrial Ecology.....	7
Efficiencies and Policies.....	9
Endnotes	10
About the Author.....	11

When Jonas Salk discovered the vaccine for polio, he brought relief from a disease that affected millions. Polio presented a concrete social problem and one that proved amenable to a single reproducible and low-cost solution. The cause of the problem was clear and its effects were plain to see; through scientific investigation the solution became clear as well. Global warming is different as it describes an effect, not a cause. The chain of events leading from what is known – that humans release enough carbon dioxide to alter the composition of the upper atmosphere – to the effect, or how an altered composition influences the terrestrial climate, is not clear. Moreover, it is evident that no single vaccine, weapon, or rocket ship will provide the solution. Nonetheless, the effects of increasing CO₂ on climate are certainly plausible.

To quote an eminent scientist considered a leading skeptic of the global warming: *“Global temperature has risen about a degree since the late 19th century; levels of CO₂ in the atmosphere have increased by about 30 percent over the same period; and CO₂ should contribute to future warming. These claims are true.”*¹ Nonetheless, legitimate scientific uncertainty remains regarding the nuances of how carbon concentrations effect weather systems and other issues, such as the feedbacks caused by clouds and the global circulation of wind currents. Because all of the emitted carbon cannot be accounted for in the increased atmospheric concentration, uncertainty even surrounds the destination of the emitted carbon, a problem known as the “missing sink”. Yet, allowing debate to center on what are, in fact, subtleties in atmospheric science draws attention away from the industrial system that generates carbon emissions.

POLITICS AND PROBLEMS

The problem may or may not turn out to be climate. Addressing the carbon-based energy system directly offers a less speculative object for concern. A more accurate and less contentious description of the problem comes from recognizing the overwhelming dependence of modern society on a carbon-based energy system. *Figure 1* shows that primary energy consumption in the United States in 2005 was dominated by hydrocarbons (i.e., coal, oil and gas).² Globally, approximately the same proportion of energy comes from the energy released by breaking the hydrocarbon bonds characteristic of coal, oil, gas and wood. These numbers show the depth of society's reliance on these fuels and the need for solutions that go beyond boutique technologies and political finger-pointing and accommodate the need for technology that can reduce carbon reliance.

Political solutions (such as the Kyoto Protocol) have been offered to address the anticipated climate problem. However, historically, technological evolution determined the course of the energy system. "Technology" conjures up images of the digital revolution where the laws governing information technology have allowed for a regular doubling of the capacity to store and manipulate information. The laws of thermodynamics will not yield as easily. The capacity and the efficiency of the energy system change slowly, but deliberately,

as demand changes (i.e., grows) and as supply technologies mature.

The fundamental natural barriers to liberating and converting useful energy are formidable. The chemical bonds found in hydrocarbons store energy very compactly and conveniently. Centuries of research have developed the means for harnessing that energy. Oil, gas and coal enjoy extensive infrastructure and also represent excellent fuels on both a volumetric and spatial basis. More ubiquitous forms of energy like gravity (i.e., dams, ocean waves and tidal energy), sunlight and wind provide a total amount of energy that dwarfs the amount of energy that humans use terrestrially. However, these forms of energy are too spatially diffuse. Real world systems designed to harness enough energy from these sources require too much land to make a difference in the global carbon budget. The scale required to implement such technologies draws attention to the fact that significant dislocations and impacts will necessarily accompany them. For example, covering the deserts of the world with photovoltaics would affect the global radiation budget, as reflective white sand dunes were replaced with sheets of black silicon to absorb the sun's energy. Thus, contrary to appearances and hopes, implementing these technologies on a scale to make a difference is not without cost.

More speculative technologies such as geothermics and fusion continue to show promise, but remain technologies for the future. The second law of thermodynamics places limits on how much useful work can be squeezed from these primary energy sources. Nature's tendency to favor disorder over order (i.e., the 2nd law), makes the goal of extracting net energy from these sources elusive.

On a volumetric basis, nuclear fuels offer an attractive option for carbon-free energy generation. While this option has met with resistance in the past, it is today acknowledged in some environmentalist quarters as well. However, strict reliance on nuclear fuels in the future will encounter finite fuel supplies as well as a rapidly expanding need for capacity to store spent fuel.³ Nuclear energy can and must, provide part of the solution, but not all.

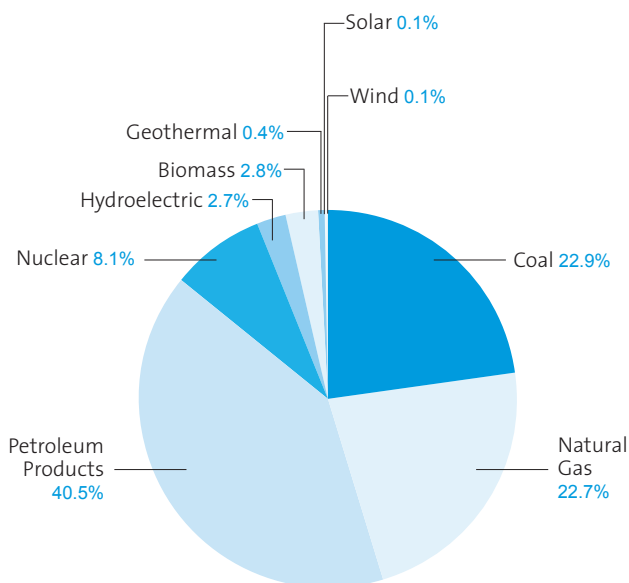


Figure 1. US Energy Consumption by energy source, 2005.
Source: US Department of Energy, Energy Information Administration.

Appreciating the technological solutions necessary to reduce the appetite for carbon in modern economies means extending the focus beyond primary energy generation to energy consumption as well. The lion's share of energy needs for running industrial societies goes to developing and maintaining roads, food supply, shelter and internal climate control. The political salience of the basic goods and the services that rely on an extensive energy system derives from the fact that these same goods and services are enjoyed by each and every member of society. To take spatial heating and cooling as one example, consider the energy needs for climate control that make places from the Arizona Desert to the Arctic Tundra possible hosts for large human populations. The energy necessary to heat or cool a cubic meter of air by 20 degrees centigrade is equivalent to the energy necessary to raise that mass of air to a height of more than one and a half kilometers. This calculation assumes 100 percent efficiency in converting primary energy into the heating or cooling necessary, a condition never satisfied in the real world. Such straightforward physical considerations show that simply maintaining bearable living conditions in the modern world will continue to substantially draw on resources.

In the past, efficiency gains have helped blunt the growth of final energy demand rather than shrink it. Such gains by themselves will not provide for the necessary performance improvements to reduce carbon emissions. More typically, greater efficiency breeds greater consumption. Amid projections of reduced coal use from the more efficient second generation of steam engines, the English economist Stanley Jevons uttered his famous paradox, "...as technological improvements increase the efficiency with which a resource is used, total consumption of that resource may increase, rather than decrease" Mr. Jevons was proven correct. More efficient steam engines led to their greater use and centuries of rising demand for coal. Driving three times as many miles in cars that are twice as efficient using the same technology helps slow the rise in demand, but does not reduce gasoline consumption. Thus, while necessary, efficiency can restrain carbon emissions, but is insufficient to reduce them.

Looking to the future, reducing carbon emissions will require a clear-eyed view of how reliant we currently are on carbon-based fuels and the systematic pursuit of fundamental technologies that moderate the emissions generated. The changes required are at the level of how society

produces the goods and services upon which modern civilization relies. Such changes will impact the modern industrial system in its entirety including the linkages between industrial sectors that have evolved in the course of the technological progress of the last 250 years. Technologies for reducing system-wide impacts are necessary for sustained progress.

THE PARADIGM OF INDUSTRIAL ECOLOGY

The paradigm of industrial ecology provides some of the operational concepts necessary to improve environmental performance in industry and begin the transformation away from a carbon-based industrial system. Industrial ecology studies the totality of material and energy relations among different industries, their products and the environment.⁴ From an analytical point of view, industrial ecology seeks to identify opportunities for reducing emissions across sectors and over the life cycle of goods and services used in the economy, focusing attention on production, distribution and consumption. The use of the term “ecology” is meant to underscore the recognized dependence of industrial sectors on one another and the preference for mimicking nature in its sublime and efficient cyclical use of energy and materials. Emphasis is placed on the use of waste products from one sector for use as input to others. While not offering a panacea, it offers a useful approach to quantifying the emissions that characterize our civilization and the means to link industrial and commercial activities with technologies that offer the greatest leverage for reducing carbon emissions.

Opportunities exist at the fundamental level. For instance, changes in how industry breaks down organic feedstocks (e.g., biomass, coal) can reduce the use of hydrocarbons for synthetic chemicals. Biosourcing represents a structural shift away from petrochemical feedstocks to those based on agricultural and forest products, often waste products. Today’s developed petrochemical systems are the result of over a century of efforts to reduce the costs of breaking down complex hydrocarbons into simple molecules and then synthesizing complex molecules for specific applications. Because bio-based systems do not have the invested infrastructure of petrochemical-based processes, systems-level design remains an option.⁵ The opportunity for utilizing the substantial quantities of residues generated by agriculture relies on advances in chemical conversion technologies, advanced separation technologies and improved catalysis. As another example, genetic engineering can be used to design trees with specific cellulose/lignin ratios tailored to the needs of the pulp and paper industry that reduce the energy necessary for paper production and allow greater numbers of trees to remain in the forest where they can soak up atmospheric carbon.⁶

For fuels themselves a variety of options exist to reduce the ratio of carbon emitted to delivered energy. A secular trend towards decarbonization has been documented for the last two centuries.⁷ These data show a consistent reduction in the amount of carbon necessary to generate a unit of delivered energy. Plans to continue using standard carbonaceous fuels and sequester carbon emissions continue to be proposed and even implemented on a small scale. *Figure 2* shows one possible scenario for sequestering carbon dioxide in several types of geological formations. However, implementing sequestration on an industrial scale must eventually find economic uses for the emissions product.

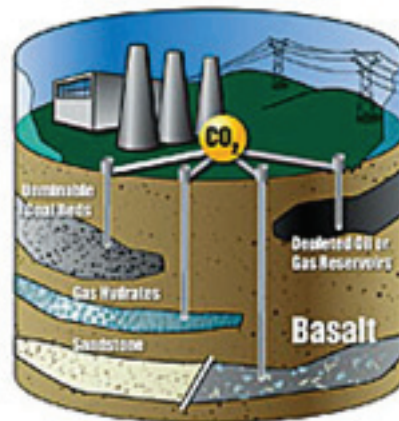


Figure 2. Illustration of proposed geological carbon sequestration options. Courtesy of US Pacific Northwest National Laboratory (PNNL). See http://www.pnl.gov/breakthroughs/summer05/special_report_pg9.stm.

Taxing emissions provides an indirect financial incentive to capture carbon emissions. More consideration must be given to productive uses of carbon emissions, such as in secondary recovery and greenhouse agriculture, to give a durable economic incentive to this method of carbon disposal that will span governments and political trends. A further source of fuels that is only now beginning to receive attention is waste biomass. As mentioned earlier, the development of non-hydrocarbon-based chemistry offers hope for the future in capturing net energy from residues now either going to very low value uses or to disposal.

Technologies in the minerals and metals sector offer promise for reducing global carbon emissions

by increasing the fraction of valuable minerals recovered from primary ores, as well as recovering energy and energy-intensive materials from industrial and municipal waste streams. For example, hydrometallurgy and biometallurgy separation technologies improve recovery efficiency while reducing energy use for refining primary metals. These technologies also provide opportunities to separate / treat waste streams and refine low-grade mineral ores (e.g., nickel from laterite) that are currently discarded. Because pyrometallurgical processes (e.g., smelting and roasting) still represent about half of world copper and zinc production, the opportunities to reduce energy use through hydrometallurgy are great.

The metals sector also offers an example for improving system-level efficiencies through process elimination and decentralized processing to reduce transportation needs. For example, more intensive concentration of iron ore nuggets to 96 percent iron content instead of today's typical 65 percent can eliminate the need for coking from the steel-making process and substantially reduce transportation costs. Aside from reducing energy for transportation, the elimination of coke ovens at integrated steel manufacturers would reduce energy use and emissions at these facilities. In considering both industrial and consumer waste streams, particle size classification can effectively segregate metals and minerals from mixed-waste

streams to enable greater value recovery from major industrial flows of material like crushed concrete, coal combustion by-products and phosphate slurries. Advanced identification technologies that can distinguish between alloys of the same metal, as well as distinguish between commercial plastic resins, offer the prospect for greater recycling of packaging and other materials from municipal solid waste and thus avoiding the need for energy-intensive virgin materials.⁸ At the use stage of the commercial life cycle, technologies exist to improve product durability, for example through the use of synthetic lubricants, coatings and specialized metal alloys to reduce wear and corrosion.

National or global level research opportunities have been identified in technology roadmaps intended to improve industry productivity and enhance future performance. These reports offer a review of current industrial activities, as well as other "Grand Challenges" or long-term visions that promise to yield substantial energy, economic and environmental benefits in the future.⁹ While the technology roadmaps address the needs of a single industry, they frequently neglect the systematic considerations of the environmental consequences beyond that industry sector. As a result, the roadmaps typically overlook research and development opportunities. More comprehensive analyses of technologies that reduce emissions across sectors must form part of the strategy for

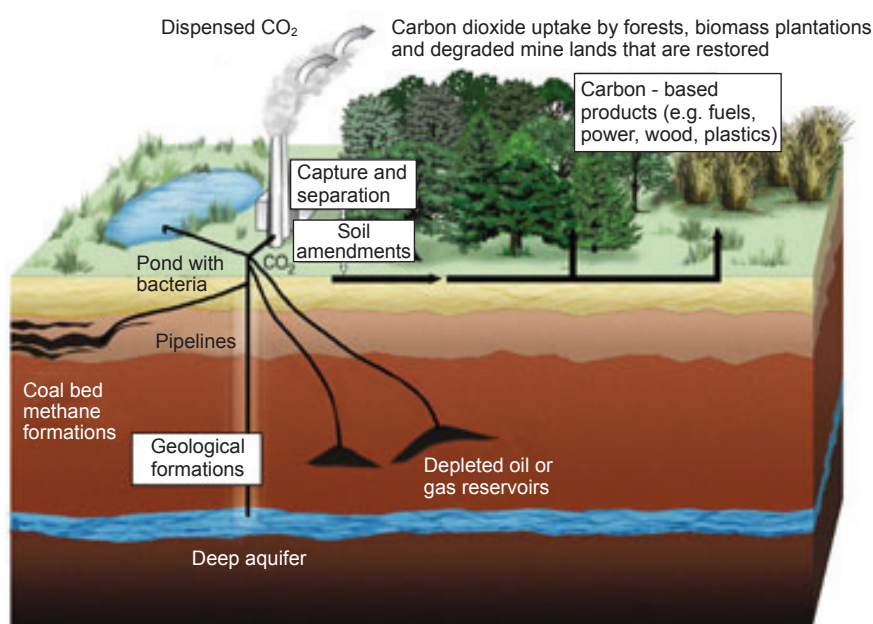


Figure 3. An illustration of carbon sequestration from a fossil-fuel powerstation.

EFFICIENCIES AND POLICIES

To review, much of the concern over global warming may be misplaced. Instead of debating possible scenarios that depend upon the subtleties of atmospheric science, attention would be better paid to addressing improvements in the fundamental structure of modern industrial economies and their overwhelming reliance on carbon fuels for energy. History teaches us that technologies that improve efficiency are welcome but will not suffice to reverse secular growth trends in the need for carbon-based energy. What are needed are more basic technologies that offer systematic improvement in the performance of industrial societies as measured in carbon emissions. Societies must be better prepared to answer such questions as: Are policies serving to break the link between economic growth and the amount of carbon employed? Are conversion efficiencies for natural resources to consumer products improving? How are shifts in the nature of the economy (from manufacturing to services and use of information technology) changing the amounts and types of materials used and the carbon emitted?

The politicizing of the climate issue should raise consciousness but should not counter pragmatism and prevent solutions. Political agreements work best when confirming facts that exist and coincide with genuine public interests.¹⁰ Unfortunately, in the case of climate, the agreements become objectives in themselves. Moreover, the numbers game they invite may reward past inefficiency or be used to score political points when the prospects for achievement are remote.

The role of public policy should be to remove biases from the existing governance of the industrial system that favor carbon-based energy forms. Relying on political agreements divorced from technological realities or on subsidies that create artificial markets that never become self-sustaining will not address the basic problem. Progress may be slow in identifying and encouraging technologies that address the need for carbon reduction at the fundamental level. Technology development and substitution, combined with openness to their economic integration offer hope for the future.

The carbon problem remains the same on hot days as well as cold ones. A changing climate in and of itself is not a catastrophe. Past changes in global climate have led to dislocations, some severe, some

beneficial. Change is in fact the norm. However, humankind is today in perhaps the best position to respond to changes. Whether a climate catastrophe occurs or not, civilization must respond. There is no other way.

ENDNOTES

- ¹ Richard Lindzen, "Climate of Fear," *Wall Street Journal*, 12 April 2006.
- ² *Annual Energy Review*. Washington, DC: United States Department of Energy, 2006. <http://www.eia.doe.gov/emeu/aer/overview.html>.
- ³ *The Future of Nuclear Power*. Massachusetts Institute of Technology. <http://web.mit.edu/nuclearpower>.
- ⁴ I.K. Wernick and J.H. Ausubel, "National Material Metrics for Industrial Ecology," *Resources Policy* 21(3):189-98, 1995.
- ⁵ Birgit Kamm, Patrick R. Gruber, Michael Kamm (Eds.), *Biorefineries - Industrial Processes and Products: Status Quo and Future Directions*. Indianapolis: Wiley Publishing, Inc., 2006.
- ⁶ Laigeng Li, Yihua Zhou, Xiaofei Cheng, Jiayan Sun, Jane M. Marita, John Ralph, and Vincent L. Chiang, "Combinatorial modification of multiple lignin traits in trees through multigene cotransformation," *Proceedings of the National Academy of Sciences*, 15 April 2003, 100:8:4939-44.
- ⁷ Ausubel, Jesse H., "Energy and Environment: The Light Path," *Energy Systems and Policy*, Volume 15, pp. 181-188, 1991.
- ⁸ Wernick, I.K., N.K. Themelis "Recycling Metals for the Environment," *Annual Review of Energy and Environment*, (1998) 23, 465-497.
- ⁹ Oleson, J., V. Haynes, B. Ramaker, R. Slough, H. Whalen, T. Sciance, M. Saft, D. Jost, W. Tamarelli, S. Turner, D. Brooks, D. Artemis, and D. Kellogg. *Technology Vision 2020: The U.S. Chemical Industry*. (1996) Prepared jointly by for the American Chemical Society, American Institute of Chemical Engineers, the Chemical Manufacturers Association, the Council for Chemical Research, and the Synthetic Organic Chemical Manufacturers Association. http://www.eere.energy.gov/industry/chemicals/pdfs/chem_vision.pdf. *Mineral Processing Technology Roadmap and The Future Begins with Mining: A Vision of the Mining Industry of the Future*. The National Mining Association, 1998. <http://www.eere.energy.gov/industry/mining/pdfs/vision.pdf>
- ¹⁰ David G. Victor, *The Collapse of the Kyoto Protocol and the Struggle to Slow Global Warming*. Princeton: Princeton University Press, 2004.

ABOUT THE AUTHOR



Iddo Wernick has worked in the field of industrial ecology - the study of industrial activity as an integral part of ecological systems - to develop methods and indicators useful in formulating public policy and commercial applications. An applied physicist by training, with a PhD from Columbia University, Dr. Wernick has taught at Yeshiva and Columbia universities, was one of the founders of Ecos Technologies, an environmental knowledge management software venture, and was a project leader at the World Resources Institute in Washington, DC. Dr. Wernick is currently a medical physicist in New York City and serves as a guest investigator at The Rockefeller University, as well as the Center for Responsible Environmental Strategies.