Review

The Conflict between Energy and Environmental Quality

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The 20th century is a period of remarkable energy technology advances that society today embraces and expects as essential for the quality of life. In parallel, a conflict has evolved between the utilization of energy resources and the quality of the environment. The current paradigm is not sustainable and major changes are not only needed, but arguably obligatory for the 21st century. The breadth of the changes anticipated is remarkable, encompassing automobile fuel, the automobile power plant, the generation of electricity, the utilization of electricity, mobility in personal transport, and the design and operation of buildings. The recognition that these changes are essential has taken fifty years through an intertwined matrix of advancing technology, political process, public policy, economics, and social behavior. The efficacy with which these changes will occur depends on the extent to which this matrix can be managed.

20世紀は，エネルギー技術が目覚しい進歩を遂げた時代であった。こうしたエネルギー技術の進歩は，生活水準を維持するために不可欠なものと信じられている。この進歩と同時に，エネルギー需要の増加と自然環境の質との対峙が生じている。現在の社会のパラダイムは持続可能なものではない。21世紀においては大きな変化が求められ，実際にエネルギー供給と利用の転換が不可避であると考えられる。自動車燃料，自動車の動力源，発電，電力利用，個人の移動手段，建築物の設計と運営など，極めて幅広い分野にわたるエネルギー技術の革新が予測される。先進技術，政策決定，公共政策，経済，社会的行動が絡み合ったマトリクスの中で，この革新が必要不可欠であると認識されるまで半世紀を要した。持続可能なエネルギー技術の革新がもたらす効果は，このマトリクスをどれだけ巧みに運用できるかにかかっている。

The Conflict

The world's conflict between ENERGY and ENVIRONMENTAL QUALITY is worsening and in crisis.

Society relies on ENERGY for both economic well being and mobility, and relies on ENVIRONMENTAL QUALITY for quality of life, the health of the public, and the health of the earth. The thirst for ENERGY is deteriorating ENVIRONMENTAL QUALITY at a rapidly increasing rate. Like a cancer or an addiction, denial preoccupies much of the world opinion and precludes, today, a systematic and unified response. The cancer, at one

time treatable with a high probability of healing, is today progressing at a rate that outpaces any politically acceptable treatment. Resolution will require an unusual courage by governing leaders. This notwithstanding, examples of proactive action are increasing in response to a discovery of increasing symptoms and growing recognition that the future health of the earth is, in fact, in crisis. California's AB-32[*1)] Act is the first major test. Remarkably,[*2)] the citizens of California recently affirmed the leadership of the California Legislature on this issue by rejecting a proposition designed to suspend the Act.[*3)] If successful, AB 32 will set a needed example for the United States and other similarly positioned countries.

*1 : Assembly Bill 32: A law passed by the California Legislature in 2006 to reduce the annual emission of carbon dioxide (CO_2). http://www.arb.ca.gov/cc/ab32/ab32.htm

*2 : "Remarkable:" Worthy of notice or attention; notably or conspicuously unusual; extraordinary.

*3 : Proposition 23: A proposition ("California Jobs Initiative") on the 2010 General Election California Ballot (November).

The Evidence

Smog.

Evidence of the conflict between ENERGY and ENVIRONMENTAL QUALITY was first witnessed on a major scale in 1948 when 20 lost their lives and thousands fell ill over five days of an exceptional atmospheric loading of particulate and oxides of sulfur in Donora, Pennsylvania. The reducing brew inflicted injury to the throat (through the formation of sulfuric acid) and the lung (by the transport of particulate laden with dilute sulfuric acid deep into the respiratory tract). The Donora incident was one of two major air pollution "episodes" where deaths were directly a result of the exposure. The second occurred in 1952 when thousands lost their lives in a London fog. The episodes established that coal, used to fuel boilers and furnaces for heating homes and businesses (London) or producing steel (Donora), was the source of the killer "smog" (coined as a combination of "smoke" and "fog").

Photochemical Oxidant.

A second major source of evidence for the conflict was chronicled by the Los Angeles Times in 1943 noting that a gray haze was "troubling" the city. While not responsible for recorded deaths, the atmospheric pollution was associated with stinging eyes, wheezing throats, shortness of breath, and an undesirable degradation in visibility. A decade later, in 1952, Professor Arie Haagen-smit at the California Institute of Technology established the

atmospheric photochemistry that gives rise to this oxidizing atmosphere. He demonstrated in a 72 liter flask that two pollutants from combustion, oxides of nitrogen (NO_x) and hydrocarbons (H_xC_y), react in the presence of the early morning sunlight to generate ozone, other oxidants (e.g., peroxyacelnitrates), and a gray haze. A few years later, a research group at the Stanford Research Institute established that the combustion process associated with the generation of electricity and the propulsion of automobiles was the principal source of the pollutants. Automobiles were also identified as a source of carbon monoxide (CO), a colorless and odorless pollutant that accumulates in the still of the morning commute hour to affect the health of a large population of unsuspecting citizens.

Criteria Pollutants.

During this period a formal distinction was made between "contaminants" in the atmosphere (i.e., chemical species that either are not present in the virgin atmosphere or increase the concentration of chemical species already present in the virgin atmosphere) and "pollutants" (i.e., contaminants that have a demonstrated adverse effect on the public health). The first "pollutant" designation was based on the nuisance of oxidant (e.g., visibility degradation, shortness of breath, stinging eyes, wheezing) and led to the first controls on automobiles and power plant pollutant emissions in California in the 1960's. The first pollutant emission controls directed to the automobile at the national level followed in 1968.

Beginning with the decade of the 1960's, health effects data were reviewed and additional studies were conducted, all of which are documented in a series of "Air Quality Criteria" documents, one for each of the criteria pollutants: Ozone (the principal component of photochemical oxidant), CO, SO_x, NO_x, Particulate, and Lead.

> Mother nature is incredibly subtle and powerful. On the one hand, fossil fuel is provided to satisfy the energy thirst of society. On the other hand, Mother Nature assigns a toxicity to trace species that, through environmental impact, is a gentle reminder for restraint.[*4)]

*4 : G.S. Samuelsen, THE RESPONSIBILITY OF SCIENTISTS AND ENGINEERS TO THE STEWARDSHIP OF THE EARTH AND ITS ENVIRONMENT (1990), Readout, No. 1, p. 4-7, July

Clean Air Act.

The experiences and discoveries in California during the 1960's set the stage for the Clean Air Act of 1970, led by Senator Edmund Muskie of Minnesota

and signed into law by President Richard M. Nixon in December. The Act established "National Air Quality Standards" based on the criteria pollutant documents, rolled back emissions from automobiles by 90% within five to six years, and created the U.S. Environmental Protection Agency. Research in the air chemistry, the public health impacts, and the meteorology associated with air pollution accelerated during the decade, and dramatic gains were realized in both combustion and post-combustion control technologies for the reduction in pollutant formation and emission. California continued to require more stringent emissions controls then the federal government for (1) automobiles through the Air Resources Board, (2) stationary sources of air pollutant emissions through regional agencies (lead by the South Coast Air Quality Management District). Ever since, California has served as a "living laboratory" for policy and policy implementation related to the challenge of improving the quality of air commeasurate with retaining a robust economy.

In the ensuing years, air quality in the major urban basins of California has improved. However, the reduction in emissions from combustion sources is (1) reaching an asymptote, and (2) being offset by an increase in both the number and operation of combustion sources. Principal examples include the increase in automobiles and the increase in miles driven, the increase in the port activity associated with international trade (ships, trucks, locomotives), and the increase in the demand for electricity. The negative impact of combustion on air quality is one reason that the conflict between energy and environmental quality is at a crossroads. A second is associated with greenhouse gases.

Greenhouse Gases (GHGs).

The first international meeting to acknowledge and proactively address increasing concentrations of GHGs in the atmosphere was held in Rio De Janeiro in 1992. Formally called the "United Nations Conference on Environment and Development" and referred to generally as the "Earth Summit," the 154 nations participating signed the "United Nations Framework Convention on Climate Change (UNFCCC)" with the goal to voluntary reduce atmospheric concentrations of greenhouse gases. Within two years, fifty nations ratified the UNFCCC and, following the terms, entered the instrument into force on March 21, 1994.

Subsequent meetings, beginning in Berlin in 1995, are referred to as the "Conference of the Peoples (COP)." COP 3 was held in Kyoto Japan in 1997 and concluded with the approval of the "Kyoto Accords" which challenged participating countries to curtail carbon dioxide (CO_2) emissions to a

percentage of 1990 levels. The percentage and acceptance of the challenge was left to the individual countries. Examples of countries that adopted the terms and proactively implemented change are Denmark, Sweden, and Germany. The United States, responsible for 25 % of the CO_2 emissions in the world, has yet to accept the Kyoto Accords.

The State of California, however, has adopted into law both the spirit and intent of the Kyoto Accords with a mandated reduction in CO_2 emissions by 2020 to 1990 levels. This translates to a mandatory requirement for the state to reach a 30% reduction over the currently projected emissions by 2020. The state also recognizes that, by 2050, an eighty percent reduction is likely. This initiative, known as AB-32,[1] is following a strict schedule of public input and implementation under a portfolio of regulations designed to meet the letter of the law. As one of the largest economies in the world and a model for meeting environmental challenges in an economically developed authority, the success (or failure) of California over the next decade will profoundly influence the world's ability to addresses the conflict between energy and the environment.

A Remarkable Time in History

The challenge of addressing the conflict between energy and the environment gives rise to a remarkable time in the history of the world that encompasses

-The natural resources of the earth
-The environmental quality of the earth
-The quality and distribution of the water resources of the earth
-The earth's human population and associated quality of life, food, and water

At the turn of the 19th to the 20th century, the automobile was just being introduced, electrical power generation was just being embraced, and the associated industrial revolution was just beginning, all of which would portend a profound impact on society and the economic engine throughout the 20th century. Combustion and fossil fuels were, and are today, the principal drivers for the revolution. Halfway through the 20th Century (in 1943 as noted above), the earth revealed its vulnerability to the pollutants emitted by combustion. Later in the century, attempts to control combustion pollutant emissions were impressive but revealed that the degree of reduction was finite and the increasing utilization of combustion powered automobiles and electric power generators offset these gains. Simply stated, during the 20th century, combustion emerged as the technology upon which society today relies for 80 % of its power, but is also the source of 90 % of the

criteria pollutants emitted in the world, and 94 % of the carbon dioxide emitted into the earth's atmosphere. Adding insult to injury, the combustion process removes oxygen from the atmosphere at the rate of approximately of 400 pounds of oxygen for every tank of gasoline consumed.

The industrial revolution and its ramifications during the 20th century were indeed remarkable, but the environmental impacts of the revolution reveal a crisis of profound proportions. With the transition from the 20th to the 21st century, we are witnessing the kernel of a new revolution (yet to be named although "green-technology" is garnering an early foothold) with the following expectations:

-Concurrent reduction of BOTH criteria pollutant and GHG emissions
-Maintenance and enhancement of a robust economy
-Conservation of natural resources

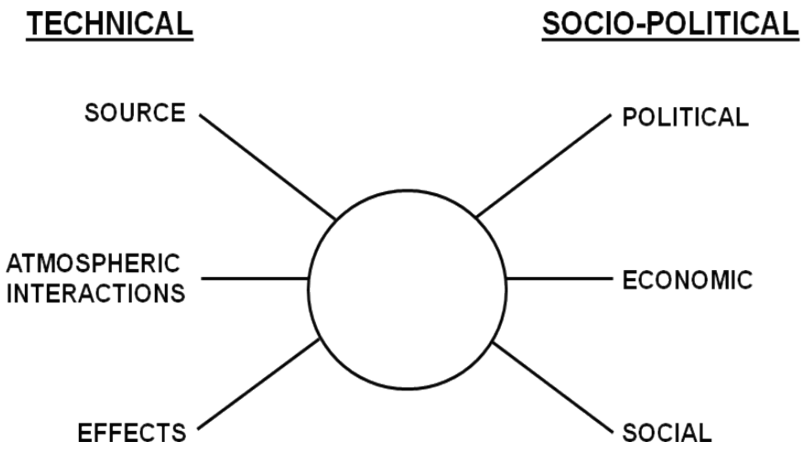
and, with even greater urgency following the events of September 11, 2001,

-Attaining fuel independence
-Enhancing national security

There is no greater cause around which the earth's peoples and governments must cooperate, and there is no greater question than whether and how this can be accomplished. The COP and California's AB-32 are key steps that may be sufficient. But time is of essence (and some would argue long past) to act proactively and aggressively.

Complicating the challenge is the entanglement between technology solutions per se, and technical solutions that are socially, economically, and politically tolerable. The diagram[*5)] below represents a "web" of interaction that makes the resolution of this conflict so forbidding (and some would argue unlikely). Historically, air pollution episodes (e.g., London and Donora) have forced the corrections needed. The current challenge with criteria pollutants and GHGs is tantamount to a cancer which is slowly eating away at the health of the earth's environment. Once the symptoms reach a crisis stage, the option for corrective action may not be available.

*5 : Samuelsen, G.S. (1971): AIR QUALITY: WHO IS RESPONSIBLE? California Air Environment, October-December .
AIR QUALITY IMPACT ANALYSIS (1979). In "Environmental Impact and Assessment Handbook," 3-1 to 3-165, McGraw-Hill.



The Direction for the 21st Century

Given this background, a remarkable paradigm shift is occurring in not one, but six major areas of the modern human experience:

1. The automobile fuel.
2. The automobile.
3. The generation of electricity.
4. The utilization of electricity.
5. The mobility in personal transport.
6. The design and operation of buildings.

Any one change would dramatically affect the daily personal experience. In combination, the changes projected are unfathomable. A benchmark is the turn from the 19th to the 20st century. In retrospect, the emergence of automobile and electric power generation and utilization over the 20st century would have been viewed as unfathomable at the time. Technology evolution was driving the change then, unbridled by consideration for environmental impact. For the 21st century, environmental quality is driving the change and driving the requisite technology.

Automobile fuel is transitioning to "dual-fuel," which encompasses a combination of electricity and carbon-free hydrogen. The automobile is transitioning to electric drive power train and a fuel cell power plant. The generation of electricity is transitioning to include (1) distributed generation[*6)] powered by photovoltaic solar, stationary fuel cells, and fuel cell/gas turbine hybrids, (2) central power plants designed for high efficiency,

the production of transportation fuel, zero-emission of criteria pollutants, zero-net water use, and the production of a near-pure stream of CO_2 for capture and storage, and (3) central sources of renewable electricity generated from wind and solar, posing the challenge of intermittency, and requiring storage or other strategies to assure grid stability. The utilization of electricity is transitioning to smart grid technology, smart appliances, and customer control in setting an economic portfolio that will automatically manage electricity demand. Mobility in personal transport is transitioning to include a greater portfolio of options, following and expanding on established models in Japan and Europe. The established models encompass fixed rail transport while the expanding options include shared-use[*7)] vehicle transport, and shared-use/station-car[*8)] transport. The design and operation of buildings is transitioning to highly-efficient designs, abundant use of daylighting, smart sensors and controls, customer managed smart control algorithms, integration of DG, coupling to transport, and distribution and use of direct current (DC) power.

Fortuitously, the environmental and ancillary forces that are driving these transitions are occurring at a time when technology is available or emerging to provide the needed capabilities. These technologies include sensors, controls, microprocessors, advanced robust and secure algorithms, user-friendly interfaces for information, personal control, and the application of personal preferences. Modeling, measurements, and scientific and engineering research are being proactively applied in combination with an increasing population of political leaders who (1) recognize that the conflict must be resolved to assure the health of the earth, society, and the economy; and (2) recognize that the future of economic health will be anchored in the development and application of a wide portfolio of green technologies.

*6 : Distributed Generation (DG): Where electricity is generated at the site of its use, and the heat that would otherwise be vented is captured and utilized for heating and cooling.

*7 : Shared-use: Where one vehicle is shared by a population of customers who reserve the use through a web-based reservation system.

*8 : Shared-use/Station-car: A Shared-use vehicle which is connected to a mass transit commute “station” with a goal to facilitate movement to and from the station.

Closure

The past one hundred years witnessed a remarkable evolution of energy transformation technologies including vehicles from automobiles to rockets, and electrical power generation from wood fired steam boilers to nuclear fission reactors. The principal strategy anchoring this transformation was

the combustion of fossil fuels. In the second half of the 20th century, the earth revealed that its finite resources cannot sustain the continuation of this approach. The most telling challenges are the contamination of the earth's atmosphere with criteria pollutants and greenhouse gases, the copious amounts of water required to generate electricity, the limited supply of fossil fuels, the increasing demand for that limited supply, and the increasing world conflict associated with protecting the supply of fossil fuels. The "wake-up" call, the recognition and acceptance of the conflict between energy and the environment, has taken fifty years to mature, and we enter the second decade of the 21st century with an intriguing parallel to one hundred years ago. Place yourself in 1910 and project the remarkable "explosion" of combustion based technology that evolved throughout the 20th century. Then place yourself in 2010 and project the "explosion" of the transformative changes in the personal experience in 21st century. Remarkable indeed.