Biomedical Technology

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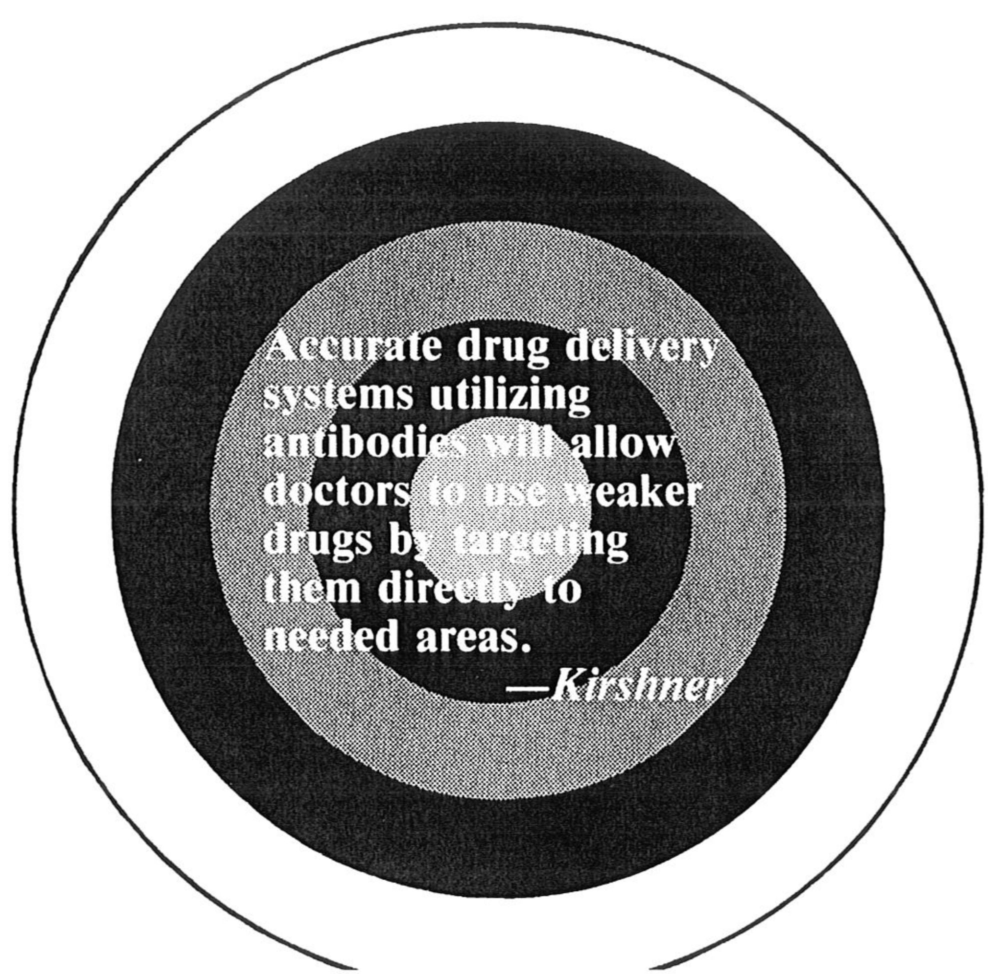
BY 2008, all branches of medicine — symptomatic, preventive, and corrective—will be altered, mainly by techniques associated with gene cloning. Prenatal dignosis by means of restriction enzymes and DNA sequencing will be employed in patients at risk for hereditary diseases with known metabolic basis. This will be accomplished by either direct visualization of the gene, or by probing linked polymorphic areas, replacing the need for detecting the gene product. While protein analysis is useful only in the very few cases where the enzyme is expressed in amniotic cells, DNA probing requires neither expression nor prior knowledge of function. The entire genome will be exposed, and 20–50 percent of the approximately 1700 known genetic diseases will be detectable *in utero,* following which corrective treatment and genetic counselling will be prescribed. In addition, carriers of deleterious genes will be ascertained by molecular methods. Moreover, conditional risks with environmental exposure given the genetic make-up will be assessed. Since associations between genetic markers and diseases of environmental origin are known, individuals will be advised as to professional and personal habits. We will no longer treat carcinogens, mutagens, and teratogens in general terms, but will be able to specifically identify individual risks. Given the polymorphic status of humans, it is certain, for instance, that some individuals will be found genetically capable of smoking, or working with asbestos without compromising their health. As to diseases for which the genetic contribution, if any, is not known, molecular techniques will be used for diagnostic purposes, to avoid traumatic interventions, such as biopsies, by correlating changes in the biochemistry of the body with symptomatic changes.

Preventive medicine will witness spectacular developments in immunology and somatic cell manipulation. Tailor-made monoclonal antibodies will enable the production of multivalent vaccines and boosters for protection against a multitude of bacterial, protozoan, fungal, and viral diseases (approximately 15 diseases/injection). These will include several forms of cancer and also caries. A potential of eradicating diseases caused by obligatory parasites of man will be developed. Given geo-political realities, however, the potential will remain largely unused. Multivalent immunology will also enable us to fight new variants of diseases, such as influenza where antigenicity sites of the virus change rapidly. Antigens directed against invariable sites such as the active sites of hemagglutinin (the symptomatic protein), will be constructed, avoiding the need for frequent changes in immunization schemes. Another breakthrough will occur with the development of methods for excision-modification of oncogenes in somatic and germ cells, thus reducing the prevalence of cancer for future generations.

Exciting developments are expected in corrective or manipulative medicine, specifically in gene transplants, directed mutagenesis, control and direction of differentiation and pharmacology involving human products manufactured in bacteria, yeast, and cell cultures. Gene transplants and directed mutagenesis will be employed to correct genetic deficiencies in specific cells. Diseases such as adult insulin-dependent diabetes or hemophilia will become non-existent. Directed differentiation by hormonal control will be routinely used in treatment of neural traumata which otherwise have an irreversible effect. The treatment will involve artificial control of axon growth. The challenge of the year 2008 in basic research will be to introduce some order in our knowledge of the endocrine system which seems to be as complex as the "zoo" of elementary particles in physics. As to pharmacological products manufactured *via* genetic engineering, problems of gene processing, post-transcriptional modification and splicing will be solved, and mass production of hormones, growth factors, interferons, oxygen-transport systems, antibodies, and histocompatability compounds, will enable treatment of thousands of diseases of diverse etiology.

—Graur



WALKING SLOWLY towards the door he realizes he has forgotten his briefcase. He walks back to the kitchen table, picks up his briefcase, and this time reaches the door, opens it, walks outside, and closes the door behind him. These are functions most of us can do unthinkingly every day, but Sam Neuman, an active man living in the year 2008, must think about these actions, for since 1980 he has been a quadriplegic. Was Sam the recipient of a miracle cure from God, or a traveling faith healer? No, he has benefitted from the work of doctors who are also engineers. Later you will meet a Twentieth Century man who has benefitted from another trend in biomedicine, the advent of non-invasive surgery, which has, as its name implies, permitted his nonintrusive surgery to replace radical surgical procedures.

Sam, though still a quadriplegic, uses a neural prosthesis which enables him to lead a normal, active life. A thought-activated miniscule computer implanted in Sam's brain sends messages through a transmitter to micro-thin electrodes implanted in muscles throughout his body. Using the simple principle that electricity makes muscles contract, Sam is able to walk. And though the computer coordinates the intricate when alternatives are available? What would happen to the institutions of family, church and state?

The implications are staggering. What will we decide?

Why indeed, devote nearly the entire societal impact essay to one key development and a series of open-ended questions? Why elaborate on what may seem farfetched in a competition where plausibility is a criterion? Why? To drive home as bluntly as I feel necessary a point which I think is grossly neglected by the great majority of people and by an alarmingly large segment of the technological community.

The point is this: We, as a society, have reached a point in our evolution where technological progress threatens to far outstrip our ability to cope with this progress, ethically, emotionally, and psychologically. To allow the technological juggernaut to roll on without similarly developing other equally important aspects of our lives is tantamount to plotting a highly complex societal suicide.

These sentiments may engender few feelings of appreciation among employees of a company notorious for its high technology. The point I make, however, is in no way an indictment of high technology, but rather of our failure to more fully explore the implications of such technology before it is brought to bear on society. If our scientists and engineers are unaware of the vast consequences embodied in their creations, if they are unable to intelligently deal with the issues raised by technological progress, how then can the less sophisticated technological layman be expected to deal with these issues? Unfortunately, I fear, if we continue to plow ahead into new technology with the same degree of introspection and examination as presently exists, our failure as a society is inevitable.

Taken in the right context, my point should be clear. All the technological impacts we can create are irrelevant if we fail to deal intelligently with the potential consequences *before* they become fact. I make my point in the hope of promoting responsibility in technological development, so that generations from now our offspring can benefit rather than suffer from our developments.

My treatment of this societal impact essay is intended to serve as kind of a well-meaning protest against the kind of mindset that often leads to progress without contemplation, technology with too little regard for consequences. It is a well-meaning protest against the mindset which promotes a competition in which students are to devote twice as much space to two specific areas of technology as they devote to the impact of those technologies. This competition might better serve both Honeywell and its entrants if it focused more clearly on societal impact. There are few enough worthwhile opportunities for students to take a hard look at the consequences and implications of technological development; a competition such as this, with more emphasis given to the societal impact, could provide just such an opportunity.

—Gates

BY 2008, the societal impacts of my forecasts will be best described as "hard choices." Due to biomedical breakthroughs in cure and rehabilitation of acute and chronic diseases, we can expect a significant aging of the healthy population. On the other hand, the computerized automation of work will radically reduce the number of employable people. Unless "revolutionary" changes are introduced into both the infrastructure of employment and the public social services, we may expect, in industrialized countries, a routine unemployment rate of about 25 percent and rising, accompanied by a two- or three-fold increase in economic disparity. One solution could be reducing weekly working hours from 40 to 30 with no change in remuneration. A second solution would be for the government to routinely intervene and provide livelihood subsidies for the unemployed and the unemployable. Both solutions are difficult to implement, and as separate remedies their economic and political effects range between calamitous and catastrophic. Mass unemployment will result in reduced influence exerted by unions, such that feasibility of increased pay per hour of work, as in the first suggestion, is at best remote. The second suggestion will result in the destruction of capitalist incentives and practices, with disastrous implications on the standard of living. A practical solution should employ elements from both suggestions, gradually administered in moderate dosages. In addition, compulsive exclusion from the working force should be mandated by various means, such as prolonging mandatory education for the young, and adjusting curricula to new employment horizons, such as health services or paramedical industries which are likely to provide employment for about one quarter of the working force.

On another level, since industrialized countries will depend less and less on imported raw materials and fuel, the disparity between developed and undeveloped countries will grow to monstrous proportions. Consequently, the industrialized countries, and especially the US, will face massive waves of immigration. The immediate effect will be a large brain drain from third-world countries which will create a cascade effect and increase disparity even more. In order to protect the employed, the most probable policy to be pursued by industrialized nations will be the tightening of immigration laws and strict implementation. This in turn will lead to both destruction of consensual moral codes and strengthening of racist tendencies. A possible alternative will be huge investments in developing nations, combined with strict control to avoid misuse. This path, however, introduces an element of interventionism. In addition, the policy will be difficult to exercise in an atmosphere of economic crisis when funds are scarce.

On the personal level, individuals will face increasingly numerous life and death decisions. Since personalized risks of ailment with environmental factors will be available, questions concerning private matters like smoking, eating and drinking habits, employment, sex, and habitation, will be made acute by *a priori* knowledge of individual perils. Much of the spontaneity and irrationality that distinguish our lives from that of automata will disappear.

In the ethical realm, society will have to decide, especially in fields such as genetic manipulation and prenatal prevention (eugenics), whether to play god or not, and who should determine that in concrete cases. A decision of

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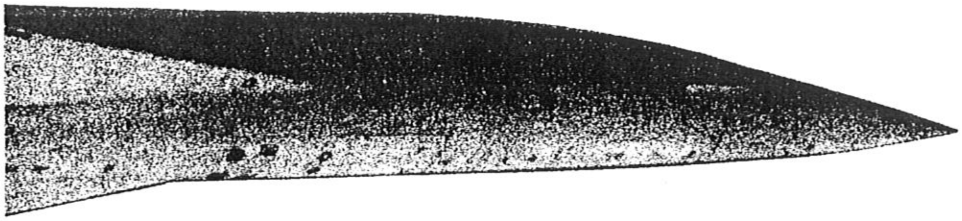

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Societal Impact

(Continued from page 37)

this kind should, naturally, start with the definition of "deleterious" *versus* "benign." In some cases, like multiple sclerosis or infant retinoblastoma, this should be easy. But what about treatable diseases like diabetes and phenylketonuria? Both answers carry an ambivalent message. Eugenics, on the one hand, decreases genetic load, but it also reduces the polymorphism in the human race, and, consequently, its chances of survival. Moreover, a paternalistic choice for somebody else (i.e. future generations) implies legitimacy of totalitarianism.

The hardest of all decisions is that we will have to make them!

—Graur

EVERY DAY, TWENTIETH CENTURY MAN is bombarded with choices. When he wants to be entertained, he may watch a program on cable, regularly programmed television, his videoplayer, or even go out to a show. When he wants to eat breakfast, he may choose new nutritionally balanced breakfast bars, sugar-coated cereal, healthy granola, or the traditional bacon and eggs. While today's choices seem overwhelming, future advances in areas such as biomedicine and solar energy will bring about an even more astounding range of choices, but each field will have quite a different impact on society.

In the year 2008, the widespread use of solar energy will express the prevalent attitude of energy conservation over consumption. Cities will no longer be plagued with choking traffic jams and pollution, as a quiet rapid transit system streaks below ground powered by photovoltaic cells above ground. The Photovoltaic Organized Wonder—called POW— will be so convenient that the barbaric custom of sacrificing over 50,000 people a year to death on our roads will be abandoned. This may lessen stress and feelings of isolation as people ride together instead of in their own private cars, each competing for a place on the road.

The energy independence photovoltaics will bring to nations, communities, and individual households will bring a spirit of self-sufficiency to our world. Each of these units may be energy sufficient if they choose, and individuals may contribute to others' as well as their own energy needs.

However, the advance of biomedical technology will have a very different social impact. Noninvasive surgery, such as the laserscoptomy performed on our heart patient Joe Hartman, while decreasing surgical trauma and increasing surgical success rates, will allow many operations which now require a lengthy hospital stay to be performed in a doctor's office. This will enable patients, in some cases, to go home the very day of the operation and avoid an expensive and often dehumanizing hospital stay. Doctors, normally, may have an engineering degree to effectively deal with advances such as laser surgery, genetic engineering, drug targeting, and the integration of mechanical parts into the human body.

In spite of the gains brought about by these advances, serious moral questions raised by this advanced technology will have to be faced. For example, as today's Olympic athletes have been tested for the presence of drugs in their systems, or—as in the case of some female athletes—the existence of a Y chromosome, tomorrow's athletes may be tested to see if their genes have been manipulated for enhanced athletic traits, or their heart has been replaced by a super-efficient artificial heart. Or , how much more human will a person be than a robot with the same man-made parts? And what about economic status: will only those who can pay benefit from these advances?

Again this will be a future with more freedom of choice, and though it is impossible to step backwards in time, how many choices can the human mind adequately deal with? We are faced with a paradox, wherein this future technology will not only bring a multitude of choices but also information to help us make these same choices.

Indeed, with seemingly unsolvable problems such as possible environmental ruin, death by cancer and the possibility of nuclear war, it is easy to predict a rather grim future. But in seeing the advances made in such areas as energy and biomedical technology, and realizing the progress that is possible, I have gained confidence and hope for the future through man's ability to solve his problems using this technology.

—Kirshner

The "Right to Information" will be a new rallying cry.
—Lewis

ADVANCES IN ELECTRONIC COMMUNICATIONS and computer science in the next 25 years will bring an almost unimaginable growth in our ability to control and generate information . . . for a price. Existing class differences in wealth and education will be exacerbated as the ability to access and use information becomes more important. The "right to information" will be the new rallying cry. Demands to provide low-cost access to the growing communications net will be acceded to by government, but educational differences will be less easily remedied, so that access may be used only for entertainment.

Individuals will have the power to copy and transmit all forms of information, sharply limiting the profits to be made from records, video provide a package of information products for a flat fee. Note that pornography, cultism, financial frauds, and interactive gambling are all possible products, causing regulatory battles to be commonplace. Some programming companies will provide all news, advertising, entertainment, computer dating, etc. from a particular religious or political viewpoint, increasing factionalization of society and growth of narrow interest groups.

Corporations and interest groups will also eagerly gather and merge data on individuals, despite public disapproval and government restrictions. Advertisers and interest groups will use computer-generated psychological profiles to tailor appeals to each individual. People will develop a healthy skepticism, of course, but the total amount of political activity will grow.

Communications will not end personal contact, however. Those organizations that try to cut costs by using at-home workers will suffer productivity losses from psychological problems and lack of creative interaction between workers. Executives will find reasons to make business trips despite teleconferencing, both for pleasure and for off-the-record conversation. Members of the general public will have the increasing ability to develop friendships and romances throughout a country via videophone. Computerized translation systems will eventually allow relatively easy conversation between speakers of different languages. (Before running off to marry a video romance, it will be wise to check whether he or she has been using the image enhancement software.)

Factory automation will continue to slowly displace low-skill workers. Clerical and service employment will also begin to drop as programs with increasing natural language capabilities are introduced. (Consumers may be given the choice between tailoring their speaking and requests to a computer's capabilities or waiting endlessly to speak to a lone human. Other organizations will offer "all-human" service . . . for a higher price.) Employment will increase dramatically in information specialties such as programming, consulting, teaching, and the new discipline of knowledge engineering. The greatest problem facing society will be developing the educational methods to train a majority of people to effectively work with information. The omnipresence of information in 2008 will do us no good if our people do not have the intellectual training to use it.

—Lewis

THE IMPACT OF THE PREDICTIONS I made for communications and aerospace will be dramatic. It must be remembered that they will occur incrementally over the next 25 years. Some people will not even be aware of the total advances being made at the time, much as today many don't realize the role of current satellites in, say, a long distance call from Boston to New York City. Public reaction and acceptance may be slow in several

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By 2008, we shall be close to energy self-sufficiency.

—Aiken

OUR 2008 ENERGY PICTURE will reflect greater changes resulting from changed mindsets than changes brought about by new technological advances or breakthroughs. Currently in the U.S. we use about 78x10^15BTU (78 Quads) of primary energy per year. I predict that by 2008 this consumption rate will be about the same—may in fact be even a little less.

Consider our current primary energy use and compare it with the 2008 prediction:

Primary Source	1983 Quads	1983 Percent	2008 Quads	2008 Percent
Imported Oil	15	19	4	5
Domestic Oil	21	27	14	18
Total Oil	36	46	18	23
Natural Gas	20	25.5	19.5	25
Coal	16	20.5	17	22
Nuclear	3	4	3	4
Renewables	3	4	20.5	26
Total	78	100	78	100

At first, we might suspect that zero energy growth (ZEG) implies a stagnant economy. This need not be so. Instead, I predict a rising GNP/Energy consumption ratio. We will be using energy more efficiently or productively by 2008, in fact 50 percent more so! This rise will be a direct result of a new understanding and appreciation of the laws of thermodynamics, especially the much maligned and often misunderstood second law. This law tells us that we should be more concerned with the way we use energy than with where we get it from, with system task efficiencies rather than device efficiencies, and with living within our global energy income than in depleting our remaining reserves of capital source energy, principally fossil fuels.

By 2008 we shall have achieved an overall second law available energy (exergy) efficiency improvement of 9 percent to about 13 1/2 percent.

This will have been achieved by:

- Widespread development and acceptance of co-generation and district heating;
- Integrated industrial energy management, using heating recuperators, waste heat boilers and recycling waste materials for energy;
- Better matching in all energy use sectors of energy demand to sources of appropriate quality e.g. electricity for work, heat for thermal work;
- Better building management practices including demand and occupancy climate control and thermal insulation.

Electrical energy will assume greater importance in the transmission and distribution of energy from source to user. Contributing to its increased flow and transmission efficiency will be 1.) HVDC transmission up to + or - 1000 kV and 2.) superconducting cables based on rapid advances in cryogenic engineering. Superconducting circuits will also be used in large AC generators and fusion reactors by 2008, when the latter will be a proven laboratory reality and prototype commercial plants based on the Tokamak principle will be on the drawing board.

We shall see a resurgence of electric traction for both passengers and freight. The electrification of the nation's railroads will be well advanced and the advent of the small P.R.T. vehicle for urban mass transit will have arrived in many of our cities. These, together with lighter and more efficient I.C. engines in automobiles for inter-city transport will have halved the country's consumption of petroleum.

Sulfur emissions leading to continued acid rain will constrain growth in coal use, and the public's continuing suspicions regarding the safety of reactors and the waste storage problem — further growth in nuclear.

Slack in decreased petroleum usage will be taken up primarily by renewable primary sources. Direct solar thermal, photovoltaics, wind, biomass, expanded hydro and geothermal. Secondary or storage sources will be an integral part of these, e.g. pumped hydro and air systems, reversible fuel cells and hydrogen generation.

By 2008 we shall be close to energy self-sufficiency, a wise and prudent response to the changing availability of our energy sources and the security of our people.

—Aiken

THE CHALLENGES OF 2008 in energy technology fall into several areas: inventory, production, storage, transport, conservation, and safety. The assumption behind my predictions is that the present oil glut represents a deviant episode within the larger picture of growing scarcity in petroleum. The glut reflects volatile political conditions and not objective geological realities. I believe that the USA will eventually have to pursue a vigorous national policy on energy, essentially along the lines of President Carter's dictum of the energy crisis being "the moral equivalent of war."

The main unknown parameter is how much fossil fuel is left and where. In 25 years we will have an answer to this question, by using a method of random oil drilling and analyzing the data by computer simulation. The method will result not only in an accurate estimate but also in rapid discovery of as many oil fields as have previously been discovered in USA's entire history. On a global scale the prospects are even rosier. The oil fields, though, will be much smaller in size so that a more efficient technology of drilling and transportation will be developed. Offshore oil platforms that can resist 100–200

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foot waves in waters 1000–2000 feet deep will be built, opening new territories to oil searches. By 2008 we will have access to deep layers of the earth's mantle, where evidence points to the existence of methane of non-biological origin. The access to this vast resource will be facilitated by the identification of tectonically active sites. Development of electronic micro-sensors or employment of animals sensitive to changes in methane concentrations in the atmosphere will enable the detection of "leakage" sites, and, thus, of possible locations for drilling.

In the fields of conservation, storage and transport, improvements will follow the massive introduction of superconductors, such as niobium-titanium alloys and organic crystals in linear and coiled forms. The efficiency rate in production and transport of electricity will reach 95–100 percent. Superconducting stabilizing devices will facilitate storage in large power networks, taming fluctuating sources of energy, such as electrical, solar, and geothermal energies. The potential of classic and modern methods in storage will be realized in mega-reservoirs where combined technologies such as underground pumped hydroelectric storage, compressed air, electrolysis, storage of hydrogen as metal hydride and sodium-sulfur batteries will be used for both static (houses, factories) and mobile (cars) needs. Further contributions to conservation will come from advanced material technology, with the development of structurally ultralight machines, cars and airplanes that will consume 25-75 percent less energy per unit of useful work.

In the realm of energy safety, the developments will come from three unrelated areas: applied statistics of risk assessment, genetic engineering, and computer technology. Risk assessment of ecologically controversial sources like coal and nuclear energy will become much more sophisticated and exact, allowing the development of a rational policy on energy matters. Computer facilitated automation, especially in fission reactors and coal operated power plants, will lessen the risk of human errors, and will revive these technologies. Genetically engineered micro-organisms will be employed to diffuse even major ecological catastrophes such as oil spills, sulfur and lead contamination of air and soil, and reduction in the concentration of ozone. Simultaneous production of nutrients and energy will be made possible by simulation of natural processes like photosynthesis and cytochrome electron transfer, and by the use of bacteria manufacturing methane and higher hydrocarbons in artificial ponds.

Incidentally, your "locker room futurism" may not be terribly far-fetched. Aerodynamic strategems have already brought *human-powered land vehicles* (HUPLAS) that can go 60 miles per hour on a level road, suggesting that short-range urban commuting, at least, is on the verge of being revolutionized.

—Graur

SORTING THROUGH HER MAIL, she opens a bill from the power company and a check falls out. Surprised, she reads the accompanying letter and finds that the electrical output generated by the photovoltaic panels on her roof has exceeded the electricity she must draw from the Solar Grid Power Co. Though Mary Fuller usually spends little on energy costs, this is the first time she has received a check from her power company. This is possible because Mary lives in the year 2008, a time when photovoltaics dominate the power industry, which allows consumer energy independence and transforms power companies into "energy brokers" distributing energy produced by others.

In the year 2008 there is a network of solar power stations on land and in space spread over a wide geographical area and united by a grid to ensure reliable energy service through the dark nights and inevitable cloudy days. Consumers interacting with these power stations use and sell the solar power as needed by utilizing an electricity inverter and meter to draw and regulate power from distant solar power plants at low-solar times, and to allow excess electricity produced by privately owned photovoltaic panels to be bought by utility plants for further allocation.

Though it seems an ideal potential fuel source, fusion power will still not be ready for commercial distribution in 2008.
—Kirshner

Formerly, in the Twentieth Century fossil fuel created energy for heat, light, and power, but the finite supply, the 1973 Arab oil embargo, and seemingly ever-increasing consumption of oil contributed to an energy problem prompting scientists to search for an economic, plentiful, and clean energy supply. The difficulty of storing wind and thermal gradient energy, the fears generated by the Three Mile Island nuclear accident, and the unanswered question of toxic waste disposal left nuclear fusion and solar energy as the primary fuels of the future.

Nuclear fusion occurs when scientists force the nuclei of two light atoms such as deuterium, tritium, or helium-3 together to make one atom or two nuclei with a smaller mass thus producing energy. But though it seems an ideal potential fuel source, fusion in 2008 is still not ready for commercial distribution. This is not surprising when we see that fusion's first chain reaction took place in 1986, about thirty years after its inception.

Meanwhile, due to photovoltaics, the solar industry became the fastest growing energy industry of the time. Photovoltaic solar cells, normally made of silicon sandwiched between two layers of metal, use photons striking silicon atoms to free electrons and produce an electric current. Photovoltaic power is abundant, clean, cheap, and as quiet as "sunlight striking a leaf."

The two major problems preventing widespread photovoltaic commercialization in the 1980s have been overcome. The first problem, storage, is no longer an issue as utility grids and electricity inverters distribute solar power to areas when needed, making storage unnecessary. Cost, the second problem, is now an asset for photovoltaic power per kilowatt unit is now less than conventional power sources of the Twentieth Century. This reduction results from the more than 50 percent growth rate the industry experienced in the 80s which drew many large investors and led to intense competition among monied manufacturers to find the cheapest and most efficient method of manufacturing and using photovoltaic cells. Research resulted in the utilization of computerized, robot-operated assembly lines, the development of cheaper materials as effective as silicon in the photovoltaic effect, and new solar design systems featuring collectors that concentrate solar rays collected in a very large area into a miniscule cell area.

Even the remotest areas have modern conveniences powered by their own low-cost photovoltaic systems or by orbiting photovoltaic satellites, called SATPOWER, that supply energy to isolated or relatively sunless areas of the world. Electric cars, invented in the Twentieth Century, employ photovoltaic cells as their electrical source, and have led to the much more commonly used, efficient, country-wide rapid transit system, which has replaced the outdated freeway and highway system.

Hence, with the advent of photovoltaics, consumers once again know cheap energy without total dependence upon monopolizing power companies, and without the fear of pollution, radiation contamination, or a diminishing supply. Homes, businesses, and commercial industry may be energy-sufficient, depending on solar power companies for back-up only. Traditional electrical power companies have disappeared or converted to solar, for solar is the power source that pays. Considering the economy, reliability, and simplicity of creating electricity directly from sunlight, it is only sensible that photovoltaics has become the major power industry by this year 2008.

—Kirshner

THAT NEW IDEAS will be developed in the laboratory and commercially deployed in 25 short years is improbable. Fusion has been tossed around the lab for decades, and construction of modern power facilities requires many years. Significant developments will therefore be limited to new applications on existing technology. Superconductors will facilitate most changes.

Superconductivity is a state of zero electrical resistance occurring in some materials near absolute zero. This allows large currents to be carried with no energy loss through resistive