The Green Machine

Ideas for using Plant Power to create useful fuels

by Janet H. Weinberg

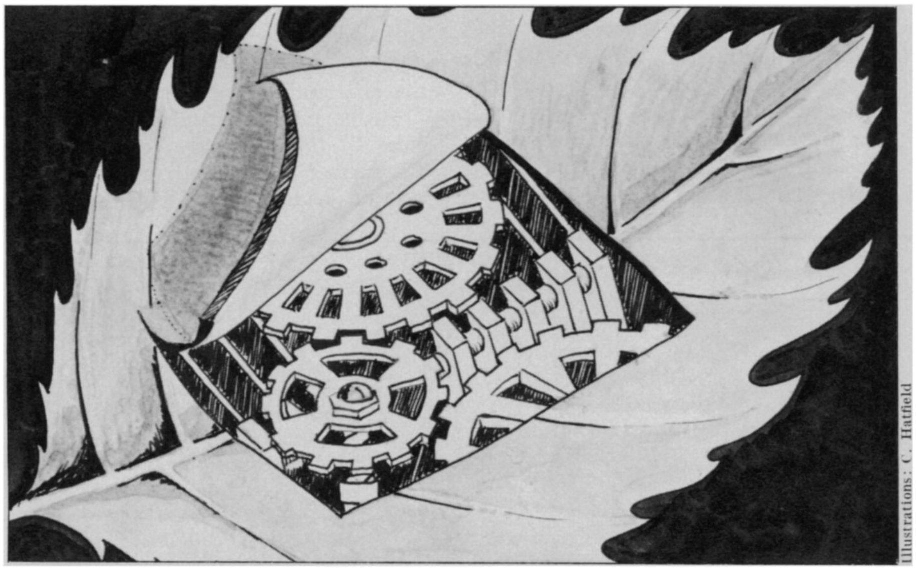
The Green Machine does not clank or hiss or roar. Its shimmering components whir imperceptibly. It does not give off noxious fumes. It gives off oxygen. And it does not use up irreplaceable fossil fuels. It creates them. The Green Machine, in fact, is not really a machine in the usual sense. It's half idea. And perhaps, as they say, it's an idea whose time has come.

A billion leafy subjects in the Kingdom Planta remind the observer that solar collectors are not a new concept. Plants have the experience of several millenia in this technology and have evolved some fairly advanced collection and energy storage systems. Through the process of photosynthesis, plants capture sunlight and turn it into cellulose—about 155 billion tons per year. That's about 150 pounds of cellulose per day for each person on earth. Besides its obvious uses for food and fiber, some scientists think this solid sunlight could be used for needed fuels like hydrogen and methane. The harnessing of photosynthesis for fuel production is the Green Machine concept—and it's starting to whir imperceptibly, even now.

On these pages are described a few of the many Green Machine projects being explored in laboratories around the country. They are forward looking, and some of them perhaps a touch unrealistic. But the search for energy alternatives is leading in lots of directions these days. And don't forget what they said when Alexander Graham Bell invented the electric speaking machine.

1.

One of the fuels most often mentioned in futuristic scenarios is hydrogen. It can be evolved from fossil fuels now, but this is expensive, and like the fuels themselves, the procedure has a limited future. Shaking hydrogen loose from its oxygen cohorts in water molecules has real promise. One can accomplish this shake-up with electricity or strong chemicals, but plants offer a solar-powered alternative. During photosynthesis, plants absorb light energy, keep it long enough to convert it to chemical energy, then store this in the form of carbohydrates. Early in the photosynthetic process, plants split water into molecular oxygen, hydrogen ions and electrons. Normally, the oxygen is released and the other chemical species are recycled. But if one could get the hydrogen ions and electrons to combine, then siphon them off, he would have a living hydrogen generator.



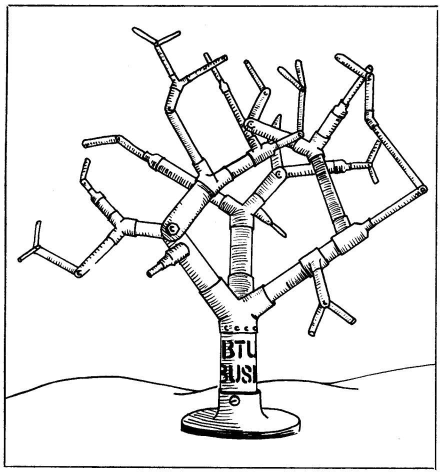
Illustrations: C. Hatfield

Several research teams are working on ways to do just this. Biochemists at the University of California at San Diego have coupled the photosynthetic elements (called chloroplasts) from spinach with an enzyme (hydrogenase) and a protein (ferrodoxin). The protein links the chloroplasts to the enzyme. When the chloroplasts absorb light and split water, the enzyme catalyzes the formation of molecular hydrogen which is siphoned off. The system works, but hydrogen yields are small. They are now trying a nitrogen-fixing blue-green alga and getting better results. Another group at Case Western Reserve University in Cleveland, headed by L. O. Krampitz, is using a different blue-green alga, hydrogenase and viologen dyes as electron acceptors. His team has gotten fairly good results thus far. Although the work is still theoretical, he thinks a 10 percent conversion of photosynthetic energy into hydrogen is possible and would help alleviate the energy crunch considerably.

2.

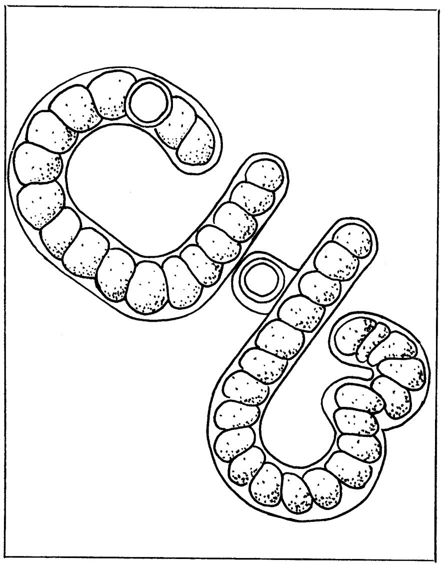
All fossil fuels have certain advantages; they are in a manner of speaking solid pieces of the sun which can be used at will. They burn and thus have a high capacity for doing work, and their energy is stored at high density. But they have disadvantages, too; rising prices, dwindling supplies, air pollution and negative political impact. There is an answer, says Clinton C. Kemp, the fast-talking vice-president of InterTechnology Corp. of Warrenton, Va. Take the good and leave the bad: Plant "Btu bushes" on energy plantations.

Kemp's concept is as simple as seed meets soil, seed sprouts, plant grows, plant is harvested, and burned for energy. Fast-growing perennials such as hybrid poplars from certain clonal lines could be grown on land not easily farmed, Kemp says. He has been raising such "Btu bushes" on abandoned farms in Pennsylvania and is encouraged by his experiment. Clone 338, for example, could produce energy for about



$1.25 to $1.45 per million Btu, he estimates, figures roughly comparable to coal-produced Btu's.

There is enough unused land in the United States suitable for energy plantations, Kemp says, to have grown *all* the fuel for the country's 1974 needs at a photosynthetic conversion rate (light energy to solid energy) of 4 percent. If the conversion rate were improved to one percent, he says, "We'd be exporting the stuff!" There are "major practical hurdles" to the large-scale use of most nonfossil, nonnuclear fuel alternatives, Kemp says. The only hurdle he sees for energy plantations is credibility.



3.

One Green Machine concept grew along with an accidental algal bloom. A series of settling ponds were built near the Napa River about five years ago to prevent pollution of San Francisco Bay by sewage effluent from the city of Napa. Within a few months, a dense bloom of algae, mostly the blue-green *Oscillatoria*, was tinting the water a pleasant hue, soaking up the California sun and the nutrients in the water. These plants were, in effect, performing tertiary treatment on the effluent by using the nitrogen and phosphorous compounds that can cause eutrophication in lakes and streams if not removed.

It occurred to some sanitary engineers from the University of California at Berkeley that perhaps the algae could be collected and "digested" by methane bacteria. These marvelous microbes break down organic matter in the absence of oxygen and release carbon dioxide and methane (CH_3), a useful fuel. Why not tertiary treatment and free fuel, too?

William Oswald, Moshe Uziel and biologist Clarence G. Golueke have since studied the feasibility of using waste-grown algae to produce methane. They cultured six species on effluents and raw sewage and found them equally digestible to the bacteria in special airtight chambers. For every pound of volatile algae solids (about 85 percent of total solids), six to eight cubic feet of gas is produced, 60 to 65 percent of which is methane. This system should be cheaper than traditional tertiary treatment, Golueke says, and might even show a profit from the methane. Besides this, he says, California state laws will require such treatment by 1980, making 10 to 20 million acres of settling ponds available for algae-methane production.

4.

Farming the sea has always been a favorite fantasy. The vastness of the oceans, the biobounty people gather from it and the specter of starving millions probably engender that fantasy. A group of researchers, appropriately from the Navy, is trying to make that fantasy a reality with their Ocean Food and Energy Farm Project. An appropriate subtitle might be "How to grow kelp for food, fuel, fibers, fertilizers, pharmaceuticals, industrial gums, chemicals, fun and profit."

Two natural barriers exist to raising plants in the open ocean: 1) sunlight does not reach the natural bottom, preventing most plant growth, and 2) on the surface, where sunlight is plentiful, there are not enough nutrients—they are down near the bottom. Howard A. Wilcox, a consultant with the Naval Undersea Center in San Diego, proposes a way to rev up the Green Machine in spite of these problems.

He would root giant California kelp, one of the world's fastest growing plants, on a mesh moored 40 to 80 feet below the surface of the open ocean. A small upwelling system powered by wave or wind energy would bring cool, nutrient-rich water from the depths to nourish the plants. Special ships periodically would harvest the top few feet of the long kelp fronds and unload them at floating food, fuel and chemical conversion stations. Here, the fronds could be digested by methane bacteria to make methane gas, or the sugars and proteins could be extracted for foods and pharmaceutical bases, the algin could be extracted for fibers and thickeners, and the inorganic salts could be removed for industrial chemicals and fertilizers. Wilcox envisions ocean food and energy farms on a grand scale. Kelp would grow in 100,000-acre beds. Each farm would have an extensive plant culturing and processing system—and probably a $1.9 billion price tag. A square mile of cultivated ocean could feed 3,000 to 5,000 persons he estimates, and yield enough energy and other products for 300 persons at U.S. per capita consumption levels. The Naval Undersea Center is starting small, however, with a hundred or so kelp plants on a seven-acre experimental farm just off San Clemente Island. Wilcox says he plans to pursue the ocean farm concept as far as practicable. □