WIRED

Dumping Iron

Ecohacker Michael Markels claims he has a megafix for global warming: Supercharge the growth of ocean plankton with vitamin Fe and let a zillion CO_2 scrubbers bloom.

By Charles Graeber

In October 1993, the *Columbus Iselin,* a ship loaded with 23 scientists from 15 international research institutes, left Panama on a mission to study one of the great riddles of oceanography. The mystery involved a dark, relatively lifeless stretch of the equatorial Pacific, a huge patch of water 250 miles southwest of the Galapagos Islands that 19th-century mapmakers called the Desolate Zone. The zone is desolate because it's short on phytoplankton, the tiny, floating surface algae that perform 50 percent of Earth's photosynthesis. Although it is rich in most of the nutrients required for plant life (phosphorous, nitrogen, silicon), the area has very little phytoplankton, a condition that scientists call "high nutrient/low chlorophyll," or HNLC. Twenty percent of the world's ocean water is HNLC, and for 70 years nobody could figure out why.

The *Columbus Iselin* set out to test a hypothesis that emerged in 1989, when an oceanographer named John Martin published a startling new theory in *Nature.* Martin believed HNLC ocean water was missing a vital ingredient: iron. Plants require minute quantities of iron to produce chlorophyll, and Martin was convinced that HNLC zones were, essentially, anemic. Sprinkle iron in the waters, he said, and they would bloom like Eden. Martin also theorized that if you grew enough phytoplankton in HNLC zones worldwide, you could lock up billions of pounds of carbon dioxide - phytoplankton converts CO_2 gas to solid carbon mass, which is effectively removed from the system when the dead plants sink to the deep ocean floor into a kind of permanent cold storage. In other words, you could potentially redirect the earth's climate.

Strange though this sounds, it's possible. Scientists have long recognized that Earth's average temperature is altered by the atmospheric concentration of CO_2, a V-shaped molecule that traps heat in the lower atmosphere like glass traps heat in a greenhouse. At the end of the last ice age, roughly 18,000 years ago, atmospheric CO_2 levels were only 180 parts per million, less than half the current (and rising) level of 366 ppm. Martin argued that huge blooms of phytoplankton were responsible for the lower CO_2 levels in that period; they reduced the earth's insulation and lowered the global temperature. With more and more of the earth's water tied up in expanding glaciers, he reasoned, winds pushed iron-rich dust from the continents' parched surfaces, creating new phytoplankton blooms and freezing even more water - a positive feedback loop for global cooling. Martin believed that if this effect were triggered again on a smaller scale, it might even counteract the contemporary problem of global warming. "Give me half a tanker of iron," he joked, "and I'll give you the next ice age."

Martin, a charismatic, polio-stricken oceanographer whom the media called Iron Man and Johnny Ironseed, found himself at the center of a blistering controversy because of these views. Oceanography is conventionally dedicated to studying the ocean, not changing it. Martin's peers warned that his "Geritol solution" could screw up the very system he was trying to study, that too little was known about oceanic dynamics to simply start casting iron on the waves.

In two weeks, 1,000 pounds of iron produced the biomass equivalent of 100 full-grown redwoods, sucking 2,500 tons of CO_2 from the sky.

Martin died of prostate cancer in 1993 at the age of 56, a few months before a research mission he'd planned, called IronEx I, set off to test iron's impact on the Desolate Zone. Two oceanography colleagues ran the experiment in his place: Richard Barber of Duke University and Ken Johnson of Moss Landing Marine Labs, a public research center affiliated with San Jose State University. For two days, while the *Columbus Iselin* traversed a 25-square-mile grid of HNLC ocean, Barber's team dumped 1,000 pounds of granular iron sulfate, dissolved in a weak acid solution, into the ship's wake. Lasers from a NASA P-3 Orion airborne optical lab zapped the waters from above, scanning for new chlorophyll.

The results were promising but mixed: IronEx I produced phytoplankton, but it yielded four times less biomass than Martin's team had predicted. In 1995, a project led by Kenneth Coale (now the acting director of Moss Landing Marine Labs) tried to increase the yield in a follow-up expedition called IronEx II. This time scientists ladled out the thousand-pound iron payload in three separate servings. And this time the dead seas sprang dramatically to life. Overnight, the HNLC waters clouded green. Fish were attracted by the harvest, and within days sharks and turtles were chasing the new food supply. By the end of two weeks, IronEx II had produced the biomass equivalent of 100 full-grown redwoods - touch-of-life results that inspired Johnson to rave about "a phytoplankton explosion of almost biblical proportions." The experimenters calculated that they had pulled 2,500 tons of CO_2 out of the atmosphere, and claimed they could do it again in desolate zones all over the world.

Michael Markels is not an oceanographer. He's a chemical engineer with a doctorate from Columbia University and an inventor who, in the 1960s, designed noncombustible atmospheres for proposed space stations and helped solve heat-transfer problems in early nuclear reactors.

Nearly half a century later, Markels is 74 and semiretired after a career in environmental engineering that made him rich. He has a new wife, a new home, a gas-guzzling Buick Park Avenue, and a big goal. He wants to put Martin's ideas into practice on a planetary scale, using iron to essentially hack a solution to the greenhouse effect. Ignoring the continuing objections of ocean scientists, Markels has created a company, Ocean Farming Inc., devoted to this prospect.

His motivation? A mix of profit and principle. Markels is an outspoken contrarian who doesn't believe global warming is much of a threat, but he's happy to sell his services to people who think otherwise. He knows that in the years ahead, nations and corporations all over the world will pay dearly for methods that allow them to meet the CO_2 emissions cutbacks established in 1997 at the United Nations Framework Convention on Climate Change in Kyoto, Japan. He figures most nations won't find the will to cut back on their fossil fuel-burning ways, so they'll have to meet the new standards by buying pollution "credits" from those that do, or from individuals who figure out ways to lock up large amounts of CO_2. He'll be in the second camp, the man with the plan to switch on the worldwide air conditioner.

Markels is well outside the atmospheric science mainstream, but he's not a crackpot. At the moment, the USDepartment of Energy is considering a Markels proposal that asks for $4 million to fund a "technology demonstration experiment." Markels wants to return to the Desolate Zone and test his patented iron-dispersion techniques on a larger scale, carefully tabulating phytoplankton growth and the total lockup of CO_2. He should know whether he's got a green light by February. If he's funded, he'll rent a research vessel and depart in early 2002 with an independent team of university oceanographers to audit the results.

Markels' idea - to actively tip the balance of the global CO_2 cycle - sounds weird, but in one sense it's as old as civilization itself: Human beings have been altering the atmosphere for thousands of years through campfires, deforestation, fossil fuels, and the ozone-eating CFCs from hair sprays and refrigerators. But only recently have we developed the technology - and the motivation - to try and change the climate *intentionally.* Increasing concern about global warming has broadened the search for creative solutions.

The result has been an open casting call for world-beating ideas, many of which are too madcap to take seriously. Some have suggested deflecting the offending UV with giant orbiting mirrors or millions of Mylar balloons. Others have proposed combing over the ozone layer's bald spot by cannon-firing soot into the stratosphere. Still others think we should pollute the atmosphere with a cooling agent like sulfur aerosols. But for every ten bad ideas, there's one that might actually work. (See "Confessions of a CO_2 Composter," page 188.) For some ecohackers, John Martin's iron theory is a model idea - bold, direct, and controversial.

As for the DOE, it may or may not end up funding Markels, but his plan is definitely getting a serious though cautious look.

Polluters pay dearly to meet clean-air standards, so the market for "credits" is booming. Carbon-eating algae could turn into a cash machine.

"The exciting thing is that Markels is proposing one of the few technologies I've seen that could actually reduce the CO_2 level of the atmosphere," says one agency source. "Ocean fertilization could actually change the temperature of the planet. But it's almost totally untested. There needs to be a lot more scrutiny and observation before we do it."

The concept's innate audacity has been an issue from the start. Before the IronEx experiments, the American Society of Limnology and Oceanography - the major professional organization for ocean scientists - urged the US government "not to consider large-scale iron fertilization as a policy option" for CO_2 reduction. In 1997, when representatives from 100 nations met in Kyoto, there was little talk of engineering the ocean. Instead, the US pledged to cut the net amount of CO_2 released through its smokestacks and tailpipes - a 7 percent reduction by 2012. Making the pledge was easy. The question was (and is) how to honor it.

One obvious answer is to unplug our appliances, leave our cars in the garage, and make factories and power plants more efficient. But efficiency is expensive - a national switch from coal to natural gas-fired power plants could double electricity bills. Outright rationing is politically farfetched. More to the point, it wouldn't be enough. Experts agree that to meet the Kyoto target, a broad range of CO_2-reducing options will be required. Of these, carbon sequestration - pulling CO_2 out of the atmosphere and storing it where it does no harm - is the most broadly attractive.

Sequestration can take many forms. For instance, you can capture CO_2 directly from smokestacks and stash it, like trash, in abandoned mines or oil wells, or store it under the deep ocean, like vinegar under oil. Japan leads the way here, spending more than $100 million a year on CO_2 sequestration. Statoil, the Norwegian energy giant, currently stores more than a million tons of CO_2 a year in gas fields beneath the North Sea. Exxon and Pertamina Oil have floated a similar plan to construct a CO_2-sequestering trench beneath the South China Sea. The DOE's Office of Science, which runs an oceanic sequestration center at Lawrence Berkeley National Laboratory, is sponsoring a similar project off the coast of Hawaii in 2001, and it helped fund four new oceanic CO_2-sequestering research projects last summer.

In the US, the only effective CO_2-sequestering system in place is a natural one that every country has: Trees and crops suck up 300 million tons of CO_2 a year. At the global warming summit in the Netherlands beginning November 13, the US State Department is requesting that these "emissions reductions" count toward our Kyoto pledge.

Markels thinks he has a better idea. If credit can be garnered for the carbon sucked up by photosynthesis, he says, then why not cultivate phytoplankton, the most abundant plants on Earth? He has structured his algae-farming plan so that he owns any carbon he sinks for the DOE. With a nod from the government and a little luck, he could turn a chunk of DOE seed money into millions of private-sector dollars.

Markels says he's perfected and patented a scalable, efficient iron-fertilization system. Apply it to a continent-sized block of HNLC ocean, he maintains, and the world's excess CO_2 will simply go away. Over the howls of oceanographers and ecologists, Markels calmly insists that if global warming is the problem, the quick fix is here.

Markels built his first company, Versar, in the '60s, when the growing environmental movement pushed through new laws that required corporate polluters to clean up in a hurry. Virginia-based Versar was one of the first to specialize in "environmental engineering" for both government and the private sector, mopping up after Superfund superfoulups, detoxing poisoned buildings, and testing hydrogen emissions from electric car prototypes. The company licenses its cleanup technology - one Versar-patented process recovers gold from raw sewage. During 25 years as owner, president, and CEO, Markels built Versar into a $70 million multinational.

These days he's slightly less busy. When I call him at his seafront home in Mason Neck, Virginia, Markels suggests that we meet over a leisurely lunch at the Cosmos Club, a famous and elite social institution in Washington, DC, that until 1988 did not allow women members. "Dress appropriately," Markels says in a gravelly voice.

I make my way to the Cosmos Club mansion, on Massachusetts Avenue not far from the White House. There, on the other side of double doors frosted with a world-on-wings insignia, I see an older man with messy locks and a trim nautical beard - it's Markels, dressed in a yachty sportcoat and a necktie dotted with tiny sailboats.

After Markels has shaken my hand and introduced me to his wife, Elizabeth, the two of them show me around the baroque *grande maison* of the 123-year-old club. In each room, servants glide through a landscape of old-world opulence: overstuffed leather chairs, Oriental rugs, and oil paintings depicting long-dead members in Great Man poses. We detour down a hallway tiled with hundreds of black-and-white photographs of Cosmos honorees. "One wall is for Nobel Prize winners, another for Pulitzers, et cetera," Markels explains, as cordial as a family dentist. "That's Justice Sandra Day O'Connor, right next to Everett Koop."

Finally we reach a buffet in the dining room. Markels, eyeing a cart of desserts, flips through his mental Rolodex for an appropriate quotation. "You know what Mae West said about temptation, don't you? 'Too much of a good thing is just enough.'"

A waiter seats us at a reserved table, another brings tall glasses of iced tea. But on this sunny afternoon, despite cornering a lion's share of the good life, Markels and his wife are dissatisfied. The day's headlines announce the findings of the first comprehensive federal study of the greenhouse effect. The report, initiated by Congress 10 years ago, warns of "significant changes" in our future. A "business as usual" approach, it says, might result in an average US temperature increase of between 5 and 10 degrees in the next century - a magnitude of warming last seen at the end of the most recent ice age. Markels is unimpressed. He considers the report sensationalistic

and irresponsible - just the sort of thing he'd expect in an election year. And he isn't buying any of it.

Given 200 boats, 8.1 million tons of iron, and, say, 11 percent of the world's ocean, Markels says, he could zero out global warming. Next question?

Sure, he says, global warming might be real, and it might even change things - but not necessarily for the worse. Markels believes the real danger isn't a greenhouse-warmed Earth - it's a greenhouse-panicked public. He ticks off various irritants that occur when too many people are running scared: high fuel prices, rioting environmentalists, 3.4 billion taxpayer dollars budgeted in 2000 to keep tabs on the global bogeyman. But, since folks are so fired up, there's only one way to hose them down: Solve the damned thing.

No one is debating that atmospheric CO_2 levels have risen steadily - from 285 parts per million before the industrial revolution to today's level of 366. And it's a fact that the earth is getting warmer. What's in dispute is whether "warmer" will mean a mere 1-degree increase or something that looks like *Waterworld;* computer models developed for the Intergovernmental Panel on Climatic Change show both extremes. By the time we've burned all our fossil fuels and the atmospheric CO_2 levels have reached 1,000 ppm, we might find ourselves in a wonderful, plant-loving greenhouse. Or we might be trapped in a steamy hell, with waves drowning the coastlines and killer hurricanes pinballing around the Caribbean so frequently that the Weather Service runs out of names.

"You always hear the *oh, my God* stuff," Markels grouses, biting the head off a grilled asparagus. "But the things I know about, they don't make everything look all that bad. The trees *love* CO_2 - they grow like mad. But you'll never read anything like that in *The New York Times.*"

"Remember the concern about coral dying?" Elizabeth chirps. "Bleaching down in the Caribbean and Florida? Well, they actually found out that it happened through nature!" She folds her birdlike hands on the tabletop, pleased. Markels nods approvingly. "And I understand some of the corals are coming back now," she adds.

Engineers both, the Markelses are wholly untouched by greenhouse guilt. In their view, civilization is a continuing triumph over natural barriers - humankind has domesticated the beasts of land and air, increased crop yield through tools and genetics, extended the length and quality of life through science and technology. Whenever nature throws us a curveball, we duck into the basement and invent a solution.

Global warming is just such a problem, and as far as Markels is concerned, we *have* the solution: iron. In an emergency, his iron-fertilization system could be deployed by a small ecohacking navy. Markels would fertilize the pristine Southern Ocean, which circles Antarctica: Not only is it one huge HNLC zone, but it's also largely uncluttered by shipping lanes and fishing boats. An iron-scattering fleet could ply the sea year-round, and the phytoplankton's CO_2-sinking progress would be measured by robots and satellites. According to Markels and his consulting oceanographer (IronEx vet Richard Barber, who is more convinced of the experiment's scientific importance than of its earth-shattering commercial potential), each ton of iron dumped could pull 30,000 tons of carbon from the atmosphere. Given 200 boats, 8.1 million tons of iron, and 16 million square miles of HNLC ocean - just over 11 percent of all the water in the world - Markels says his flotilla could zero out 8 gigatons of CO_2 each year, the entire global fossil-fuel emissions enchilada, all for an annual cost of around $16 billion. Crisis over. Next question?

"People are demanding that something be done," he says, shaking his index finger. "Sure, there are always going to be people who take the position that anything you do to the ocean is evil. But

what I'm proposing isn't new. I'm just doing it in a new way."

Markels explains that Mother Nature has been fertilizing with iron for eons. Today, naturally occurring iron enrichment is a key ingredient in the world's richest fish fields. Iron-rich dust from the Gobi Desert blows east to fortify the salmon fisheries off Alaska; the largest natural iron-fertilization field is situated off the coast of Peru, where an upwelling of iron and other nutrients creates a fish yield significantly larger than the combined catches of the US and Mexico.

Markels sees a world of potential in those statistics. He claims ocean fertilization is modeled on these natural "iron nourishment" processes - all he wants to do is provide a little push, plus a revenue model that sends most of the revenue his way.

After lunch, Markels chauffeurs Elizabeth and me across the Potomac for a peek at Versar, a brick industrial park nestled amid the trees and electrical towers of suburban Virginia.

He released the day-to-day reins of his company seven years ago. But at a stage in life when other men reach for the golf clubs, he still goes to the office every day to tinker with his pet project. Officially he's chair emeritus at Versar, but the nameplate on his door reads OCEAN FARMING, INC. (OFI) / GREENSEA VENTURES LLC.

Mother Nature has been fertilizing with iron for eons. And naturally occurring iron is a key ingredient in the richest fish regions' high yields.

OFI headquarters consists of a dignified cubicle in the back hall of the Versar complex. There's a paneled desk set surrounded by diplomas and honor society plaques, a view of the parking lot, and a large rectangular whiteboard. And on this board, in erasable blue marker beneath his beloved Mae West quote, is a series of statements arranged like a proof to a mathematical theorem. Markels reads top to bottom, his voice booming with moral authority:

EVERYTHING IS CONNECTED
EVERYTHING IS UNCERTAIN
ANYTHING MIGHT CAUSE ANYTHING
DON'T DO ANYTHING ...
SOMETHING HAS TO BE DONE!

This logic poem figures prominently for Markels - in the course of our interview he refers to it almost a dozen times. It encapsulates his gripes about the current state of the global warming debate: The problem is too complex to tinker with, and yet too serious to ignore; the only answer is to study it until it's too late.

"I have a friend in the Office of Science at the Department of Energy," Markels says. "I said to him, 'It looks to me like you don't want to solve the problem.' You know what he told me? He said, 'No, absolutely not! We want to study it! If we solve the problem, then everybody'll be out of a job!'" Markels leans forward and grins broadly. "Nobody wants to fix it!" he says. "Nobody."

Nobody, he means, except himself, the man who developed IronEx research into a patented system. The primary issue was efficiency. Markels says that as much as 95 percent of the iron that IronEx II dissolved in solution and then dumped into the ocean oxidized immediately and sank to the bottom, useless for photosynthesizing plankton. To prevent this waste, Markels began looking for a chelate - a molecular ring that protects iron from oxidation just as a shark cage protects a skin diver. The most obvious choice was editic acid (EDTA), a pharmaceutical compound commonly used in vitamin pills. But EDTA is expensive. Markels needed a chelate that's affordable by the ton.

"I took a look at lignic acid," he says. "It's a by-product of the papermaking process - they used to dump it in streams. It turned the water brown, it stank, it killed the fish. I gave it a try. Turns out it works much better than EDTA. And it's cheap!"

Markels stands stiffly and reaches between the chemistry handbooks and company reports on his bookshelf to procure a baggie of gray bullets - shiny june bug-sized pellets of compressed iron dust, fortified with lignic acid chelate. He places a few magic beans in my palm. "We tested these in the Gulf of Mexico, and they work fine," he says, adding that the acid will be too diluted in seawater to cause pollution problems.

Another shortcoming of the IronEx experiments, he says, was scale - at 25 and 40 square miles respectively, they were too small. Diffusion spread the iron beyond the monitored test zone, and the patch was so small that plankton grazers swooped in freely from the sides, gobbling up the green buffet. To counter this, Markels and Barber realized they needed to think bigger.

Markels' DOE proposal involves laying a fat patch of chelated iron dust across 5,000 square miles of the Desolate Zone. Markels expects to trigger a huge phytoplankton Genesis - the largest ever - and to sink between 600,000 and 2 million tons of CO_2 in the process. It would be a big, flashing neon sign advertising the Markels plan to the fossil fuel-driven world.

As Markels knows, the future of CO_2 control will most probably be modeled on the 1990 Clean Air Act, which regulates pollutants like hydrocarbons, nitrogen oxides, and sulfur dioxide (the acid in acid rain). The Act made it possible to over-comply with new emissions standards, then sell excess efficiency - in the form of pollution credits - to polluters seeking to offset their emissions bottom line. The result was a thriving pollution-credit economy, complete with brokers, marketplaces, and agents. A similar scenario for carbon is still being born - the Kyoto Protocol is unratified, as are standardized, verifiable protocols for carbon trading. But experts predict such laws and protocols will appear in the future. A Kyoto draft report estimates that in anticipation of this future carbon-trading economy, about $150 million has been spent so far on CO_2-sequestering forestry programs, with another $200 million in the pipeline.

Right now, most of that forest-based carbon sequestration money goes to the third world. Jungle real estate is cheap, and greenbacks are a persuasive argument against clearing farmland and timber. According to Peter Calvert, an emissions consultant who supervised a Malaysian-based carbon-sequestering forestry project for PG&EEnergy Trading, countries like Costa Rica have made a business out of this. "Many potential carbon offset projects are sited there," he says. "The dollars are very big."

Markels aims to show big business that sequestering CO_2 in the ocean is more reliable and more secure than forestry approaches. "On land you need rangers and fences, and a single forest fire can wipe the whole thing out," he says. "And you can't guarantee that the have-nots aren't going to come in, raze the area, and start planting cocaine or something." By contrast, in the proposal now before the DOE, Markels writes that his iron process is "environmentally benign ... easily measurable ... and permanent." And it costs $2 per ton of carbon sequestered, where forest-based approaches run as much as $20 a ton. When a full-blown carbon economy arrives, Markels hopes to provide a bargain-basement service to corporations looking for a way to meet their carbon reduction obligations.

What do the eco-experts think of Markels? Not much. One of his biggest detractors is Penny Chisholm, a professor in MIT's departments of civil/environmental engineering and biology, and a colleague and friend of John Martin's. She didn't set out to be a spoiler, one of those everything-is-connected types Markels likes to lampoon. "I'm not a tree-hugger," she laughs, "but a lot of people

think Markels is nuts." The problem, she says, is that although Markels' plan sounds seductively simple - pour iron in the ocean, sink the algae, walk away - it isn't.

"The counterargument is complex," says Chisholm. "It has to do with biological systems." For Chisholm, what's missing is a reasonable discussion of scale and time frame. Naturally iron-rich zones like the Peruvian coast waters evolved over eons, which allowed for the fine-tuning of local flora and fauna in a way that led to ecological sustainability. It's a process that Markels, whatever his talents, can't mimic by simply dumping iron overboard.

"Yes, he will create an algae bloom in the middle of the Pacific, a bloom of a species that doesn't usually thrive there," she says. "And yes, there's an algae bloom off the coast of Peru. But they won't be the same thing. The parallels aren't really parallels."

Chisholm explains that, taken together, the organisms in the sea make up the food web - the "metabolism" of the earth. It's an interconnected system, balanced in the same way as the organs in the human body. But when you change the species composition in the ecosystem, you change they way they function in that metabolism. The effect on the earth would be a lot like the effect of replacing a person's heart, liver, and spleen with organs from other animals.

One problem: Huge amounts of sinking organic matter can trigger production of methane, a greenhouse gas 30 times worse than CO_2.

"Maybe we could get by with pig organs," Chisholm says, "but they probably wouldn't do the job as well, and our metabolism would get out of whack. Chicken organs? They wouldn't work at all - too small. We'd die." She doesn't believe that Markels could "kill" the earth, but he could change it in ways we might not like. "And try as we might, I don't think we could fix it afterward."

According to oceanographer John J. Cullen of Dalhousie University in Nova Scotia, other problems could stem from the types of plant life produced by iron dumping. There are thousands of varieties of phytoplankton; fertilization will simply multiply the types that happen to be present. "The outcome is unpredictable," Cullen says. "It's possible that toxic blooms could develop." What's more, even "good" phytoplankton might be bad news. Huge amounts of sinking organic matter can trigger the production of methane, a gas with a greenhouse impact 30 times greater than that of CO_2 (although methane's half-life is only 25 years, compared with CO_2's 25,000 years). Over time, massive phytoplankton death might also result in widespread hypoxia - an oxygen-poor aquatic environment - and even extended regions of anoxia - that is, no oxygen at all.

Markels counters by saying that if, God forbid, anything goes wrong, he'll simply pull the plug. Without his iron pills, the phytoplankton bloom would "shut down in 20 days."

When I relay this strategy to Chisholm, she responds with a nervous laugh. "First of all, we don't know what, in this context, 'wrong' is. We know nothing about the deep ocean: zero. The idea that you can stop this when the 'going wrong' is 50 to 100 years down the line - it doesn't work."

Jim Bishop is the codirector of the Department of Energy Center for Research on Ocean Carbon Sequestration at the Lawrence Berkeley National Lab - a think tank funded by the DOE Office of Science, which doesn't have a vested fiduciary interest in any one patent or technology. He's met Markels, thinks he's a reasonable guy, and believes that what he proposes might even be possible. But Bishop doesn't think the government should just turn Markels loose with several hundred square miles of ocean.

"Ocean fertilization is certainly worthy of investigation; otherwise the DOE wouldn't consider it," Bishop says. "But ocean plants are a whole new game. At this point, we don't have enough information to confidently predict which way the ocean will go. People can go to a stretch of sea

and turn it green - John Martin demonstrated that. But what we still don't know is what's happening down below."

Doug Carter, director of planning and environmental analysis in the DOE Office of Fossil Energy, also has concerns. "The potential for using this technology to take care of climate problems is enormous," he says. "But frankly, I would want to have an *awful* lot of confidence that nothing wrong was going on. We have to study it, and that will take years. We're not a bunch of cowboys running out, doing reckless things with the ocean commons. That's not our style."

Oceanographers like Chisholm, Cullen, Bishop, and Carter echo a point Markels has heard a thousand times - that more tests are required to make a responsible demo feasible. And they say that what Markels is now proposing - a "technology demonstration experiment" to impress potential clients - hardly qualifies as science.

"But, fact is, science is no longer leading the way for industry on environmental policy," acknowledges Kenneth Coale, whose most recent IronEx-style research proposal just received DOE funding for 2002. "When you have Texaco and Exxon running ahead of you, your job as a scientist is no longer to research what *could* happen - it's to research what *is* happening, what will happen, based on what industry is doing. It's playing catch-up. The cat is out of the bag, and now I feel like we're chasing cats."

Markels has heard this criticism so many times that he carries his answer in his wallet. It's a quote from Henry Miller, written on a scrap of paper: "The new always carries with it the sense of violation and sacrilege," he reads reverently. "What is dead is sacred. What is new, that is different, is evil, dangerous, or subversive.'"

Richard Barber, Markels' friend and adviser, doubts that ocean fertilization is going to save the world. But he's convinced it's worth testing, if only to ease the sting from Kyoto laws - and generate crucial science in the process. "There's no lost opportunity for the rain forest people," he says, "and it seems to be safe, cheap, and completely reversible." What's more, Markels is offering a scientific opportunity to finally answer the question: Why didn't IronEx work better? "If there's going to be a big political debate about this, we should at least know what we're talking about. And right now we don't have a clue."

The only major player who can't comment on Markels' ocean fertilization plan is John Martin, the man behind the original IronEx theory. But the two have a lot in common. Like Markels, Martin was besieged by controversy over his out-of-the-lab approach. The oceanographer saw both the risks and the prize on the other side. "I will never advocate shoot-from-the-hip iron fertilization without the detailed research to understand it," he wrote one critic, just before his death. But, he said, a little iron in the ocean might be preferable to a warmed climate. "I agree that the ideal would be to have the average American get out of his car; have the Chinese not develop their coal resources; have the Brazilians not cut down the rain forest," he wrote. "However, we don't live in an ideal world."

After our interview, the Markelses want to return to their freshly built three-acre waterfront spread, but they generously offer to drop me off at the Washington-area Metro on the way. As I settle back into the tan leather interior of their Buick, Elizabeth chats politely about the trials of building a new home. They've finally finished a seawall that will keep the waves from gobbling up their shorefront, she says, but what with the EPA insisting that the little tuft of marsh grass on which it was built was a wetlands habitat, and then the thing with the eagles - well, she had to admit, she was glad to be done with it.

Iron in the ocean might be preferable to climate change, wrote John Martin, the father of iron fertilization: "We don't live in an ideal world."

Traveling with the Markelses, I find it easy to imagine the greenhouse nightmare from their perspective: a Kyoto-run world that permanently garages my Buick, and where state inspectors spot-check my thermostat while my fuel bills double. A world that hops onto bicycles, huddles around geysers, and invests heavily in hydrogen technology. In a future like that, people dependent on fossil fuels would become fossils themselves. For the Markelses, who view such regulation as illogical nonsense, it's a future worth fighting against.

But what, exactly, do you want from ocean fertilization? I ask Markels. What is your ultimate hope for that? Markels glances into his rearview mirror and then returns his gaze to the lines of traffic. "Well," he says. "It wouldn't bother me if the government were to buy my idea. Then, presumably they would do what they do in other situations like this - license the technology and make sure they can implement it by keeping ships at the ready."

You mean by treating this program like a branch of the military? An army trained to go out and spread iron on the ocean in case of extreme greenhouse warming? "Yes," Elizabeth says, scrunching around in the passenger seat. "To keep up, quote, readiness." She nods solemnly. "And I would feel good in my gut if our tax money would stop paying for so much expensive research that isn't needed."

Like what?

Markels laughs: "Like putting a giant sunlight-reflecting mirror into orbit."

"And putting up windmill farms over acres and acres in California," Elizabeth adds.

But don't those work?

"Oh, they work," says Markels, putting on his turn signal, "but ..."

"Only when the wind blows," Elizabeth jumps in. "They kill birds. And oh, the noise! Plus, how much CO_2 does it save? Not enough to make a difference after you factor in all the energy required to manufacture them."

"You know," Markels says, digressing pointedly, "back around 1900, the average life span was about 40 or 45. Now it's close to 80. That's because of our lifestyle, which is dependent on fossil fuels." He starts to inch out into traffic. "And that's not going to change."

Outside the car, it's the end of a weekday, and the Beltway is filling up with a good portion of its 200,000 commuters. As I sit in climate-controlled comfort, traversing the interstate at 23 miles a gallon, I imagine another world, one with Michael Markels in the driver's seat and a planktonic greenhouse solution ready to roll: a world where the government maintains a corps of iron grunts at Guantánamo Bay; where seawalls are enough to keep the ocean from gobbling the land; where Elizabeth and Michael and the rest of us can all go back to our normal lives as freewheeling first world consumers. A world utterly free of greenhouse guilt.

It was, I must admit, quite a comfortable ride.

Charles Graeber (cagraeber@hotmail.com) *wrote about canine cloning in* Wired *8.03.*