BROOKHAVEN
NATIONAL LABORATORY

Building 134
P.O. Box 5000
Upton, NY 11973-5000
phone 631 344-2345
fax 631 344-3368
http://www.bnl.gov/

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News Release

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Contact: Peter A. Genzer, 631 344-3174 or Mona S. Rowe, 631 344-5056

This briefing describes research to be presented at the 226th meeting of the American Chemical Society, September 7-11, 2003, in New York City.

Coal-Eating Bacteria May Improve Methane Recovery

NEW YORK, NY — Scientists at the U.S Department of Energy's Brookhaven National Laboratory are exploring the use of bacteria to increase the recovery of methane, a clean natural gas, from coal beds, and to decontaminate water produced during the methane-recovery process.

Mow Lin

Methane gas, which burns without releasing sulfur contaminants, is becoming increasingly important as a natural gas fuel in the U.S. But the process of recovering methane, which is often trapped within porous, unrecovered or waste coal, produces large amounts of water contaminated with salts, organic compounds, metals, and naturally occurring radioactive elements. "Our idea is to use specially developed bacteria to remove the contaminants from the wastewater, and also help to release the trapped methane," says Brookhaven chemist Mow Lin.

Lin's team has developed several strains of bacteria that can use coal as a nutrient and adsorb or degrade contaminants. They started with natural strains already adapted to extreme conditions, such as the presence of metals or high salinity, then gradually altered the nutrient mix and contaminant levels and selected the most hardy bugs (see details).

In laboratory tests, various strains of these microbes have been shown to absorb contaminant metals, degrade dissolved organics, and break down coal in a way that would release trapped methane. The use of such microbe mixtures in the field could greatly improve the efficiency and lower the associated clean-up costs of coal-bed methane recovery, Lin says.

To learn more about this work, see the talk given by Lin during the Division of Fuel Chemistry's "Synthetic Clean Fuels from Natural Gas and Coalbed Methane: 30 Years Progress Since the First Oil Crisis" session on Thursday, September 11, 2003, at 3:30 p.m. at the Jacob Javits Convention Center, Room 1A13. This research was funded by grants for high-school and undergraduate student research at Brookhaven Lab from Brookhaven Science Associates and DOE's Office of Science.

Please Note: Mow Lin passed away unexpectedly on Friday, September 12, 2003 while traveling to Beijing.

Other briefings in this series include:
Researchers Develop Counterterror Technologies,
Nanoscale Model Catalyst Paves Way Toward Atomic-Level Understanding,
Reverse Reaction Helps Isolate Important Intermediate,
Designing a Better Catalyst for "Artificial Photosynthesis"
Using Ions to Probe Ionic Liquids, and
Coal-Eating Bacteria May Improve Methane Recovery.

The U.S. Department of Energy's Brookhaven National Laboratory conducts research in the physical, biomedical, and environmental sciences, as well as in energy technologies. Brookhaven also builds and operates major facilities available to university, industrial, and government scientists. The Laboratory is managed by Brookhaven Science Associates, a limited liability company founded by Stony Brook University and Battelle, a nonprofit applied science and technology organization.

METHANE AND GROUNDWATER

Can methane occur naturally in groundwater?
Yes. Throughout Alberta methane is a common, naturally occurring, dissolved gas in groundwater. The methane is held in place through underground pressure; reducing this pressure allows the methane to be released.

When a water well is drilled into a coal zone, methane gas can appear immediately or later in a well's lifespan. In some parts of Alberta, water wells are frequently drilled in coal seams.

Can methane be harmful?
Methane is non-toxic and non-poisonous. Accumulation of methane gas in an enclosed space such as a well pit, pump house, or well casing can cause an explosion.

Will methane in water burn my skin?
No. Methane alone will not burn your skin.

When does methane in groundwater become dangerous?
Methane dissolved in groundwater cannot explode. However, it can bubble out when brought to the surface. If you notice excessive bubbling in your hot or cold water supply, you should vent the water well.

Does gas content naturally change in a water well?
Yes. Natural factors such as seasonal variation, age of the well and a change in pumping rate can affect a well's gas content. Improper well maintenance can encourage the growth of bacteria that produce methane.

Shock chlorination keeps wells clean and bacteria-free. But can water well shocking produce contaminants where methane is present?
Administered properly, shock chlorination procedures kill bacteria in water wells.

Following proper shock chlorination procedures (as outlined in *Water Wells that Last for Generations*) by-products should not be present in the water well supply.

Health Canada recognizes that disinfectant use has almost completely eliminated the threat of waterborne microbial diseases. Health risks associated with not shocking wells that have bacteria in them far exceed the health risks of shock chlorination.

What steps should an owner take, where methane is naturally occurring in the water well?
Install water well and distribution system components to vent the methane. For more on this, see *Water Wells that Last for Generations* on the Alberta Agriculture Food and Rural Development website addresses listed below.

What steps should the owner take, if the methane could be due to resource development?
An owner or occupant who observes changes in water quality or quantity **after** the drilling for oil, gas or coal bed methane, should contact the resource company involved and phone Alberta Environment's 24-hour environmental hotline (1-800-222-6514) to officially register a complaint.

What can a landowner expect after they register a complaint?
All complaints registered with Alberta Environment are tracked in a database and referred to an Alberta Environment staff member for follow-up.

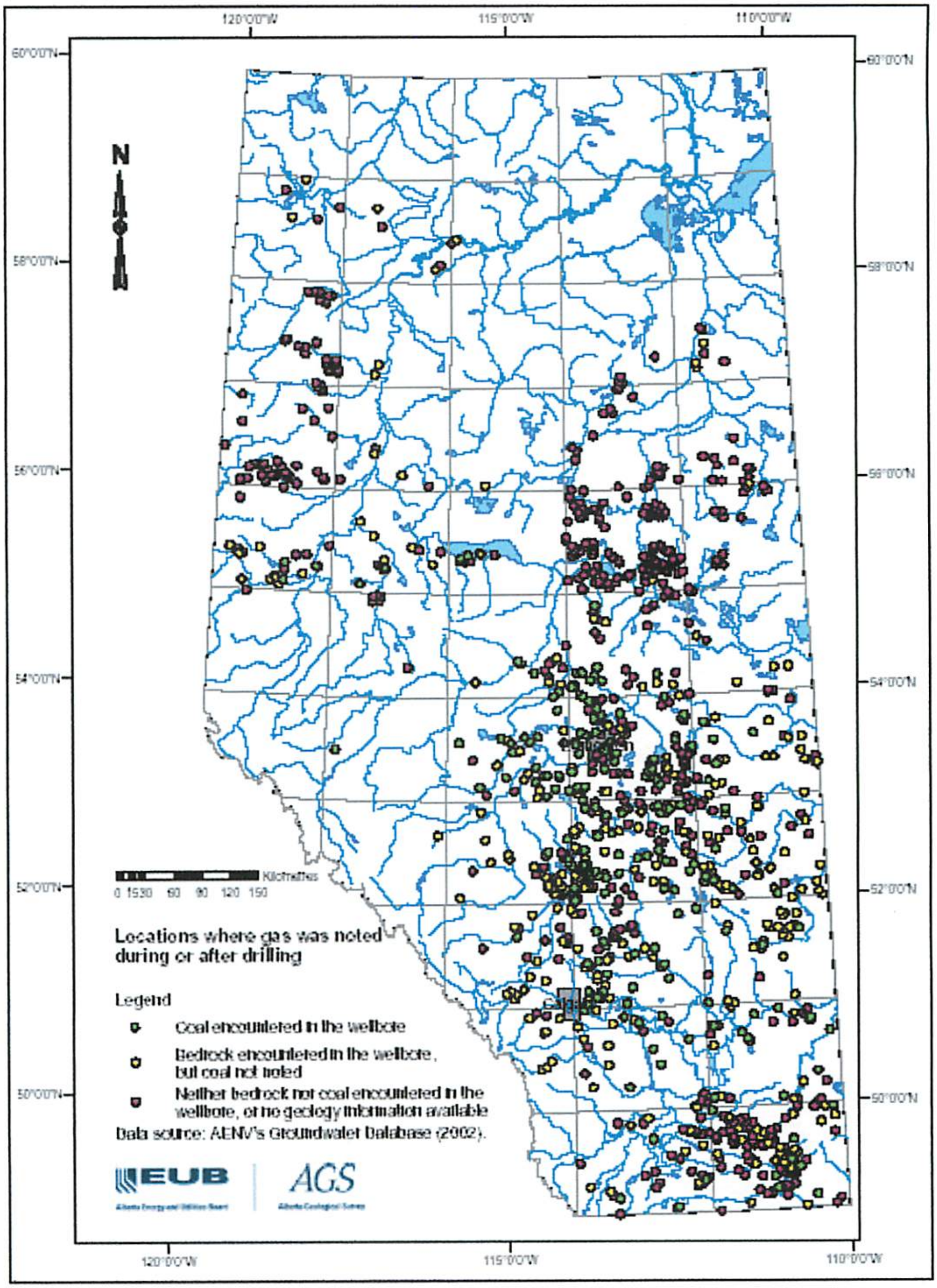
What can an owner do to protect a water well?
Keep a record of the well's water production capability, water quality, water level and any presence of gas.

If there is shallow coalbed methane development in your area, have your well tested. Baseline testing results provide information that can assist an investigation.

For specific protective measures, visit Alberta Agriculture Food and Rural Development's web site at
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/eng9758

For more on dissolved gases such as methane in your well water, visit
http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex637

Who can landowners contact with questions regarding water wells?
If the well is producing methane, contact your local Alberta Environment or Alberta Agriculture Food and Rural Development office, or the local Regional Health Authority.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Locations where gas was noted during or after drilling
Legend
Coal encountered in the wellbore
Bedrock encountered in the wellbore, but coal not noted
Neither bedrock nor coal encountered in the wellbore, or no geology information available
Data source: AENV's Groundwater Database (2002).
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Search Results

21 - 30 of about 121,000 for **coal bed methane bacteria** - 0.34 sec. (About this page

21. Statement of Basis **Coal-Bed-Methane** General Permit for Temporary Discharge (PDF)
"Daily Quantity (#/day)" - The quantity, in number per day, of **bacteria** or other ... damage to stream banks, stream **beds**, ditches, or other waters of the state ...
deq.state.wy.us/wqd/WYPDES_Permitting/WYPDES_cbm/downloads/3-0001.pdf - 1270k - View as html

22. **Coal-bed methane** being created by microbes, researchers say ...
... managed properly, can help turn **coal-bed methane** into a renewable energy source, ... indicates that anaerobic microbes, or **bacteria** that live in the absence of ...
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23. coalbed **methane** development in the intermountain west: primer (PDF)
Bacteria that obtain nutrition from. **coal** produce **methane** as a by-product. 7. **Methane** attach ... Some **coal beds** may produce gas. but be too deep to ...
cookinletoilandgas.org/Shallow **Coal Bed Methane**/.../CBM_Primer.pdf - 2615k - View as html

24. Handbook on CBM Produced Water (PDF)
Introduction to **Coal Bed Methane**. Introduction ... to biogenic **methane** produced by methanogenic **bacteria**. Minor production of CBM has been ...
all-llc.com/CBM/pdf/CBMBU/CBM BU Screen_Chapter 2 Introduction to **Coal Bed Methane**... - 534k - View as html

25. FuturePundit: **Methane** Producing **Bacteria** Found In Oil Fields
... of **bacteria** into **coal beds** would be very problematic because the **bacteria** would ... of the PRB **coal-bed** resource as substrate for biogenic **methane** creation is the ...
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26. **METHANE** AND GROUNDWATER (PDF)
of **bacteria** that produce **methane**. Shock chlorination keeps ... drilling for oil, gas or **coal bed methane**, should contact the resource company involved ...
waterforlife.gov.ab.ca/coal/docs/Methane_and_groundwater_factsheet.pdf - 86k - View as html

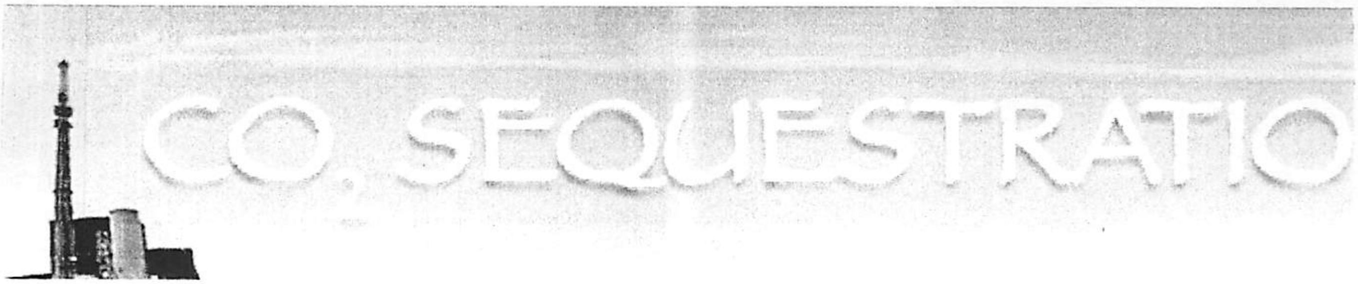
27. Researchers are studying whether microbes can :: ENN
... are studying whether microbes can be manipulated by science to expand the life of **coal-bed methane** wells in the Powder River Basin of Montana and Wyoming. ...
www.enn.com/today.html?id=11104&ref=rss - 19k - Cached

28. Researchers Hope Bugs Speed **Methane** Take, Researchers Hope Microbes Can ...
... science to expand the life of **coal-bed methane** wells in the Powder River Basin ... out when to expect the next **coal beds** based on what we already know ...
www.cbsnews.com/stories/2006/08/21/ap/tech/mainD8JKVDQ00.shtml - 65k - Cached

29. **Coal-bed methane** being created by microbes, researchers say
... managed properly, can help turn **coal-bed methane** into a renewable energy source, ... indicates that anaerobic microbes, or **bacteria** that live in the absence of ...
casperstartribune.net/articles/2004/11/18/news/wyoming/... - 37k - Cached

30. **Methane** - Free Encyclopedia
fossil fuel extraction : 20 % See **Coal bed methane** extraction ... **bacteria** found in rice plantations : 12 % biomass anaerobic heating or combustion ...
www.wacklepedia.com/m/me/methane.html - 5k - Cached

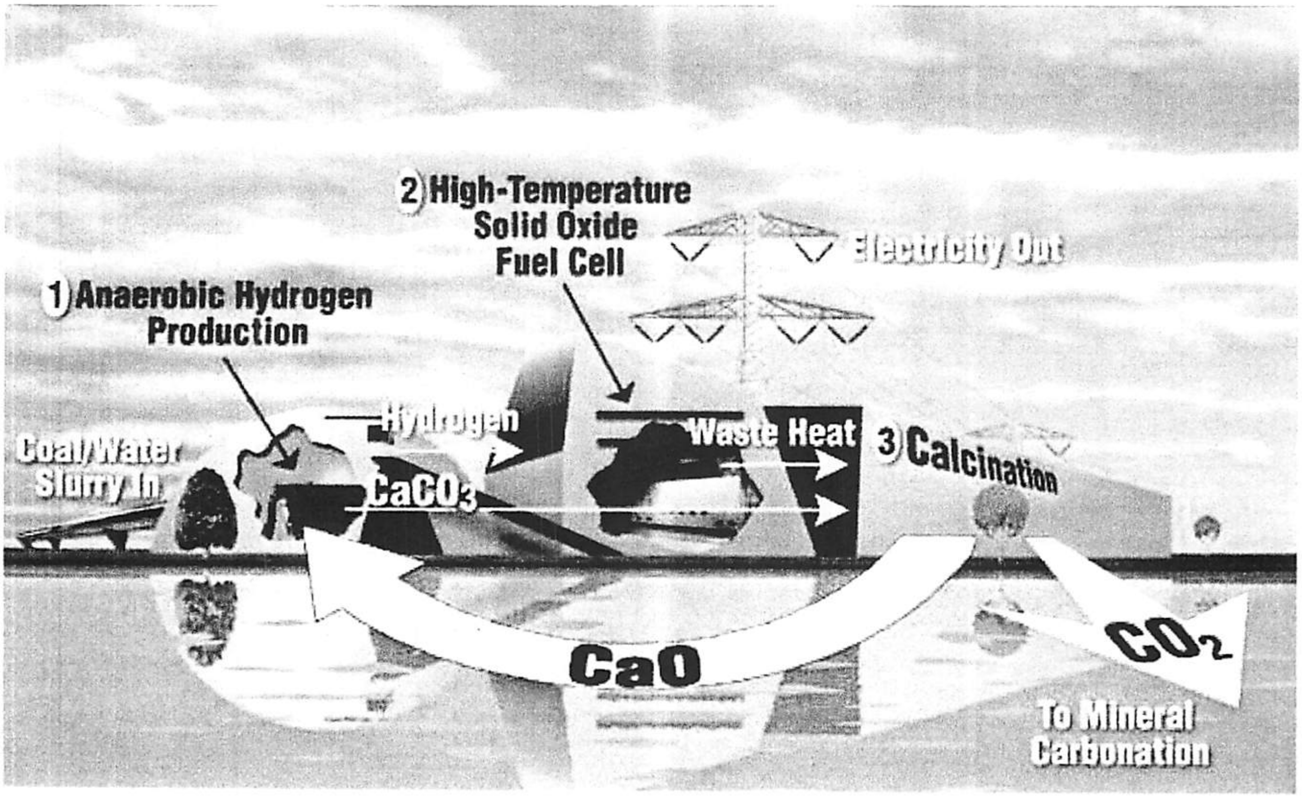
Prev 1 2 3 4 5 6 7 8 9 10 Next



ZEC-Zero Emission Coal Technology

What is ZEC?

Zero Emission Coal technology is technology for generating electricity from coal without emissions to the air. It is being developed with the intent to use mineral carbonation for disposal of the carbon dioxide produced, although, technically, any form of sequestration would be possible for use.



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Who is Researching ZEC?

The research is being lead by the Los Alamos National Laboratory together with the Zero Emission Coal Alliance (ZECA) Corporation, although they are not the only ones in the field.

Why coal as opposed to natural gas or other fuel?

Coal has two big advantages over natural gas: 1) abundance on earth and 2) price.

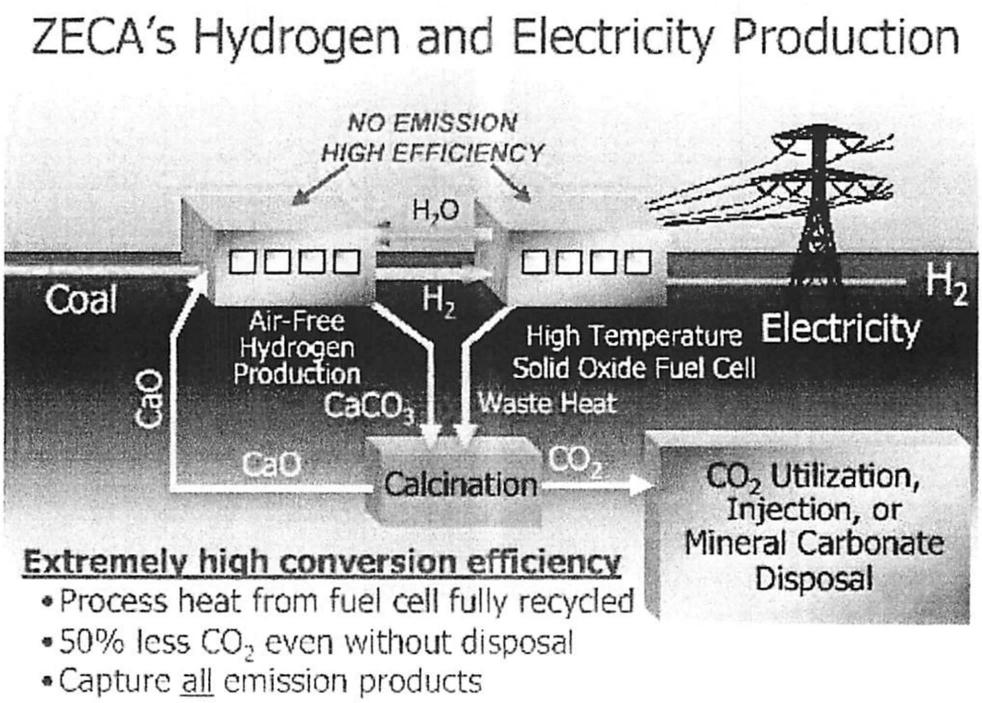
"Coal cost at the mine mouth is about \$0.50 to \$1.00 per GJ. The cost for natural gas is \$2 to \$3 per GJ by comparison. The low cost of coal is in part offset by larger handling coast and larger cleanup cost. When it comes to carbon sequestration, the lower cost of coal allows one to budget a certain amount for CO_2 disposal without losing the competitive edge. For example, the price difference between nuclear and coal suggests a buffer of about $40 to $60 per ton of CO_2. Relative to renewable options like solar energy the margin is even higher. Another comparison is relative to natural gas. For every dollar difference in price between natural gas and coal, the cost of CO_2 capture and disposal can go up by $22/ton of CO_2. This scenario assumes that the price difference between coal and gas is reduced because coal needs to pay an additional cost for removing that amount of CO_2 by which it exceeds the output from natural gas power plants [coal produces more CO_2 than does natural gas]." [1]

How does ZEC work?

"[The ZECA process] combines a coal-based electric power plant with a process for safely and permanently disposing of the carbon dioxide generated. The power plant is an ultra-efficient, coal-based power plant using an updated version of the CO_2 acceptor process. Hydrogen is produced from steam and coal, and electricity from hydrogen in solid oxide fuel cells. Lime acts as the CO_2 acceptor. By removing CO_2 from the reaction products, the carbonation of lime drives the water-gas-shift and steam reforming reactions forward. Carbonation also provides the heat necessary to run the hydrogen production to completion. To recycle the lime, we calcine the calcium carbonate with the waste heat from the solid oxide fuel cells while generating a concentrated stream of CO_2 ready for disposal. The coal gas is circulated through the plant without any gaseous emissions. Pollutants from the coal, like nitrogen, sulfur, and heavy metal compounds or fine dust particles, leave the cycle either in liquid streams, or with solids. The process includes CO_2 disposal by a chemical reaction with readily available mineral rock to form inert mineral carbonates. The reaction is exothermic and thermodynamically favored. The resulting materials are inert and environmentally benign." [2]

What are the advantages of ZEC? [3]

- CO_2 is captured as part of the process and no distinct separation step is required
- Fuel energy is captured more efficiently from hydrogen than from the coal from which is it derived.
- Because the process is essentially a closed loop, the removal of any residual contaminates from coal becomes much easier and all contaminates are completely contained within the system.
- Air emission standards need not be considered since nothing is vented to the atmosphere and no extra effort is required to do so.
- Impurities may cycle through the process numerous times before removal, allowing concentrations to increase and making the removal process easier and more efficient.
- The technology is resistant to incomplete reactions due to the continuous cycling of the reactants.
- Unreacted hydrogen from the fuel cells is recycled.
- CO_2 is continuously removed by reacting it with CaO.



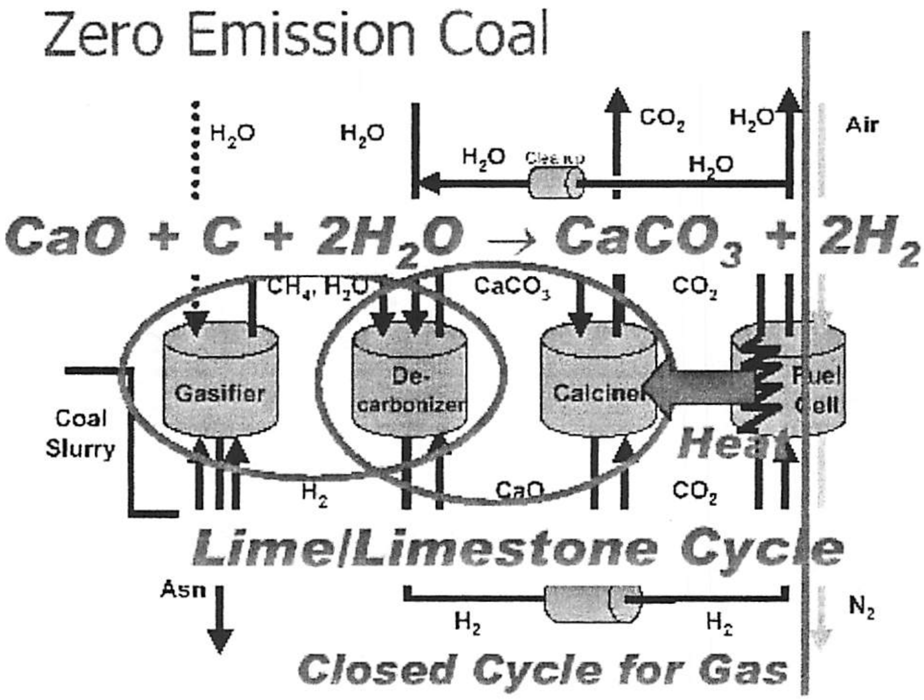
source: Lackner 10/7/02 p.18

What are the disadvantages of ZEC?

- If the hydrogen is used as a fuel for a hydrogen economy, a new infrastructure must be built for transport, storage, and utilization. [4]
- Continuous requirements for coal mining which scars the earth's surface

How does ZEC relate to Mineral Carbonation?

The current zero emission coal process under development includes carbon dioxide removal by exothermically reacting the CO_2 with mineral rock to form a thermodynamically stable, inert material. The end results, magnesium carbonates, are stable, guaranteeing permanent disposal, and have no adverse effects on the environment. The amount of mineral needed for ZEC technology is large in terms of volume, but the amount of deposits on earth greatly surpass the mankind's limit of producing carbon dioxide, and the areas invaded by the mining of the mineral are much smaller than those of coal mines needed to recover enough coal for the process to be feasible. [5]



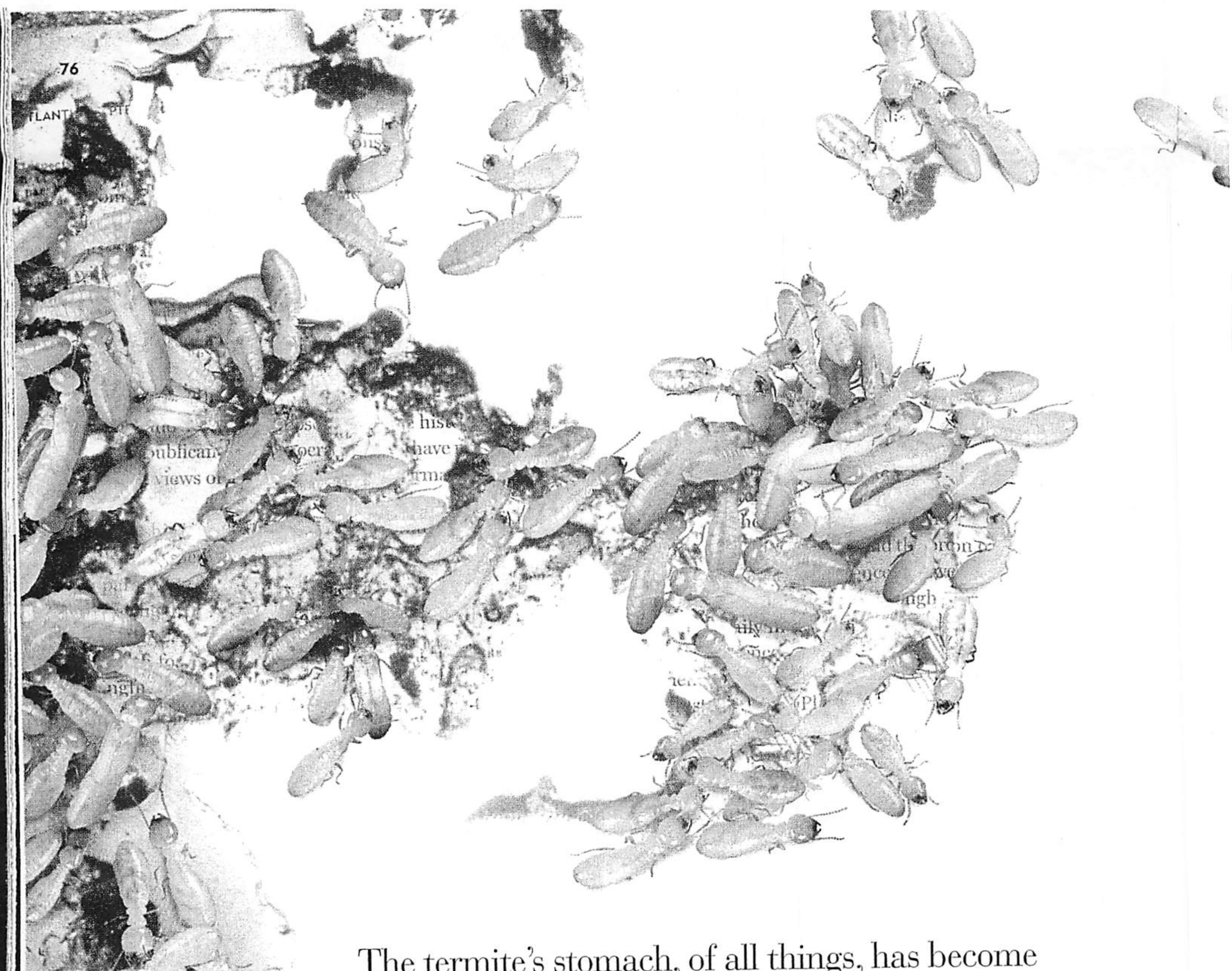
source: Lackner 10/7/02 p.15

Schematic of the anaerobic hydrogen production and fuel cell system. Material flows are idealized to the predominant components. The major reactions are as follows:
Hydrogasifier: C + 2H2 ® CH4, H2O(liquid) ® H2O (gas)
CaO Reformer: CH4 + 2H2O ® CO2 + 4H2, CaO + CO2 ® CaCO3
Calciner: CaCO3 ® CaO + CO2
Fuel Cell: 2H2 + O2 ® 2H2O

top

references
[1] Yegulalp et al. p.59
[2] Lackner et al. p.58-59 (12/2001)
[3] Lackner et al. p.59-61 (12/2001)
[4] Spiro et al p.42
[5] Lackner et al. p.59 (12/2001)

Email: eglazer@princeton.edu or mokun@princeton.edu



The termite's stomach, of all things, has become the focus of large-scale scientific investigations. Could the same properties that make the termite such a costly pest help us solve global warming?

Gut Reactions

BY LISA MARGONELLI

PHOTOS BY PHOTO RESEARCHERS, INC. AND NATIONAL GEOGRAPHIC

For more than a hundred million years, termites have lived in obscurity, noticed only by the occasional hungry anteater or, more recently, by dismayed homeowners. Other social insects, such as bees and ants, are celebrated for their industriousness and engineering feats, but popular culture has not gotten around to cheering on termites for theirs—even though they build mounds as tall as 20 feet, which may be oriented north-south as accurately as if plotted with a compass, in order to maximize heat from the sun. The extraordinary powers evolution has bestowed on termites—some protect the mound by spraying chemicals from nozzles on their heads at intruders, while others have snapping mandibles that can decapitate invading ants—have similarly failed to elevate their status. On the contrary: last year, scientists at the London Natural History Museum called termites "social cockroaches" and proposed reclassifying them, in a paper brusquely titled "Death of an Order."

The more closely one examines the termite, the more mysteries one finds. In some species, if a termite discovers a contamination in the mound, it alerts everyone else, and a hygiene frenzy begins. As a disease passes through a mound, the survivors vaccinate the young with their antennae. When a mound's queen is no longer capable of reproduction, the workers may gather around her distended body and lick her to death.

PHOTOS BY PHOTO RESEARCHERS, INC. AND NATIONAL GEOGRAPHIC IMAGE COLLECTION; PHOTO ILLUSTRATION BY MELISSA BILEY

The greatest mystery of all is found in the worker termite's third gut, which is delineated by an intricately structured stomach valve, as unique from species to species as individual snowflakes are and, in its way, just as lovely. The size of a sesame seed, the third gut contains a dense mush of symbiotic microbes. Many of these microbes live nowhere else on Earth; they depend on adult termites to pass them on to the young by means of a "woodshake," a microbial slurry.

This microbial mush may be a treasure trove for the human race. Recently, sophisticated genetic sequencing produced an inventory of more than 80,000 genes, spanning some 300 microbial species, from the guts of Costa Rican termites. These findings, published last November in the journal *Nature*, got a lot of attention, not for the quantity of microorganisms—after all, the human mouth contains 600 species of bacteria—but for their complexity, and in particular for the fact that among them are 500 genes for enzymes able to break down the cellulose in wood and grasses.

With oil prices at historic highs, the quest is on to turn such plant materials into a replacement for gasoline—call it grassoline. Since 2007, U.S. energy policy has been shaped by the premise that we can brew enough biofuels to replace 35 billion gallons of gasoline by 2017, and 60 billion by 2030. Corn ethanol has been a bust, blamed for wasting water, exhausting croplands, and causing tortilla shortages in Mexico and rice shortages in Asia. For all these problems, it currently contributes the equivalent of only about 4.2 billion gallons of gas a year. And the carbon dioxide emitted in the process of growing and fermenting corn and then distilling and burning ethanol is nearly as much as that emitted by extracting, refining, and burning gasoline.

Wood and grasses seem to hold more promise. They contain chains of thousands of glucose molecules that could be made into so-called cellulosic ethanol and then burned like gasoline, while releasing just 15 percent of gasoline's greenhouse-gas emissions. But there's a catch. Wood has evolved to keep its sugars to itself, covering them with lignin—a substance that gives cell walls rigidity—and then locking them in a matrix of cellulose and hemicellulose protected by complex chemical bonds. Because these sugars are so hard to get at, our output of cellulosic ethanol is still, after decades of research, just 1.5 million gallons a year—less than 1 percent of one day's gasoline consumption.

But where humans have failed, the termite succeeds—spectacularly. A worker termite tears off a piece of wood with its mandibles and lets its guts work on it like a molecular wrecking yard, stripping away sugars, CO_2, hydrogen, and methane with 90 percent efficiency. The little biorefineries inside each termite allow the insects to eat up $11 billion in U.S. property every year. But some scientists and policy makers believe they may also make the termite a sort of biotech Rumpelstiltskin, able to spin straw—or grass, or wood by-products—into something much more valuable. Offer a termite this page, and its microbial helpers will break it down into two liters of hydrogen, enough to drive more than six miles in a fuel-cell car. If we could turn wood waste into fuel with even a fraction of the termite's efficiency, we could run our economy on sawdust, lawn clippings, and old magazines.

And so the termite may be poised for its moment in the sun. Speaking last year about moving toward a biofuel economy, Energy Secretary Samuel W. Bodman pointed to the termite-to-tank concept, asserting, "We know this can be done." Another official called it a promising "transformational discovery." Suddenly the termite is everywhere, from *Popular Science* to *Congressional Quarterly Today* to *Wired*. With the audience for energy speeches and articles so small and wonky, it's too soon to say that the little bug has exactly become a celebrity (although it did recently rate a footnote in *Vanity Fair*). But in some circles, it has attained a certain status as the pest that could solve our energy problems, transforming geopolitics and agriculture in the process. "Deus ex termita," you might say.

Offer a termite this page, and its microbial helpers will break it down into two liters of hydrogen—enough to drive six miles in a fuel-cell car.

Perhaps—but it won't be easy. Last year, in an initiative that has been compared to the Manhattan Project, the Department of Energy founded three Bioenergy Research Centers, which collectively house scientists from seven government labs, 18 universities, and several private companies, and are aimed at making cellulosic ethanol competitive with gasoline within five years. The effort, which has $375 million in funding, is focused on plumbing the structures of woods and grasses and learning how various creatures break them down; genetic modifications, scientists hope, could then enable us to make cheaper fuels. The centers are expected to come up with ideas that can be commercialized—actually making them more like Bell Labs, say, than like the Manhattan Project.

Started two years earlier, the termite project described in *Nature* is based on the same model of public and private collaboration, and is now an important part of the bioenergy initiative. Indeed, termites might be seen as an "indicator species" for the larger effort—and, as scientists are learning, they are full of devilish details and vexing complications.

In 2005, the microbial ecologist Falk Warnecke, of the Department of Energy's Joint Genome Institute, traveled with researchers from Caltech and the San Diego biotech company Diversa to Costa Rica, where they opened up a termite nest in a tree. The group dissected 165 worker termites, freezing the contents of their third guts in liquid nitrogen and shipping them to Diversa's lab. After extracting the DNA from the microbial cells, Diversa sent a sample to the institute to be sequenced.

Housed in a low brick building in Walnut Creek, California, the Joint Genome Institute is sequencing the genes of hundreds of plants and microbes that might be useful for energy production and environmental cleanup; it is a key part of the Bioenergy Research Centers. Originally formed as part of the Human Genome Project in the late 1990s, the institute has its roots in the Department of Energy's decades-long interest in tracking genetic mutations in atomic-bomb survivors and nuclear workers. The scale of its current mission becomes evident as soon as you enter the lobby, where a TV screen displays a ticker that tallies sequences by the minute, day, month, and year. When I arrived at about 10 o'clock one morning last spring, the day's total stood at 25,555,288 DNA base pairs, the twinned nucleotides that are the building blocks of genes. Every second, another thousand base pairs joined the tally. Employees call this incessant data stream the "fire hose." The institute now sequences as much DNA in an hour as it did in all of 1998, and the pace is planned to double by the end of the year.

Even for people accustomed to avalanches of data, the effort to map the contents of the termite's third gut is extraordinary. "A disgusting mess of a data set," says Phil Hugenholtz, the head of the institute's Microbial Ecology Program. An angular Australian in his 40s, he speaks in rapid bursts, like a human fire hose. Traditional genomic analysis sequences one organism at a time, but Hugenholtz is a leading practitioner of metagenomics—the new science of sequencing genes from whole environments of microbes at once, and sorting out the resulting jumble of loose DNA code with the aid of computer science, statistics, and biochemistry. Metagenomics is not only breathtakingly fast; it allows us to catalog genes that were previously unknowable because so few types of microorganisms—fewer than 1 percent of all species of bacteria—can be cultured in a lab. Many biologists regard metagenomics as a scientific revolution akin to the invention of the microscope. In practice, though, it's a sloppy art.

When the sequencers finished, they had 71 million letters of DNA code in tiny fragments. They sorted the fragments, assembled them into longer chains of genes, and scanned the genes to determine their likely functions and which of the 300 microbes they might have come from. Scientists then looked for combinations of chemicals that might be enzymes, comparing the results to enzymes known to work on cellulose. The metagenomic picture of the termite's third gut that has so far emerged is a portrait of codes and probabilities—more sophisticated than a photograph from an electron microscope, but less satisfying, because so much remains indefinite.

Next, the scientists set about the long process of figuring out how all the parts work. "It's like trying to learn about a house when someone's given you nothing but the blueprints—and they're all ripped up," Hugenholtz says. Still, the blueprints were stunning. The termite gut contained much more than enzymes involved in breaking down wood into sugars: for example, there were a hundred species of spirochetes closely related to syphilis but here devoted to, among other things, producing hydrogen. There were also 482 appearances of a mysterious giant protein that Warnecke says looks like the international space station. He drew me a picture of a long, Lego-like scaffold with different enzymes plugged into it, hypothesizing that the protein might help strip sugars out of wood. But that was only a guess: "One of the disadvantages of finding so much is that you don't know what it all means," he told me.

MORE ON THEATLANTIC.COM
For a multimedia look at the world of termites, narrated by Lisa Margonelli, visit www.theatlantic.com/termites.

Hugenholtz and Warnecke began sifting through the questions raised by the metagenome. Why do termites have 300 microbes and 500 different genes to degrade cellulose? How do you go about deciding which microbe is the most important? Do some termite species have stronger guts than others? And what on Earth was the space station doing? To tackle these questions, they needed more termites. They took some from cow patties on a Texas farm, surprising the elderly landowners by asking for a signed waiver on whatever intellectual property might develop.

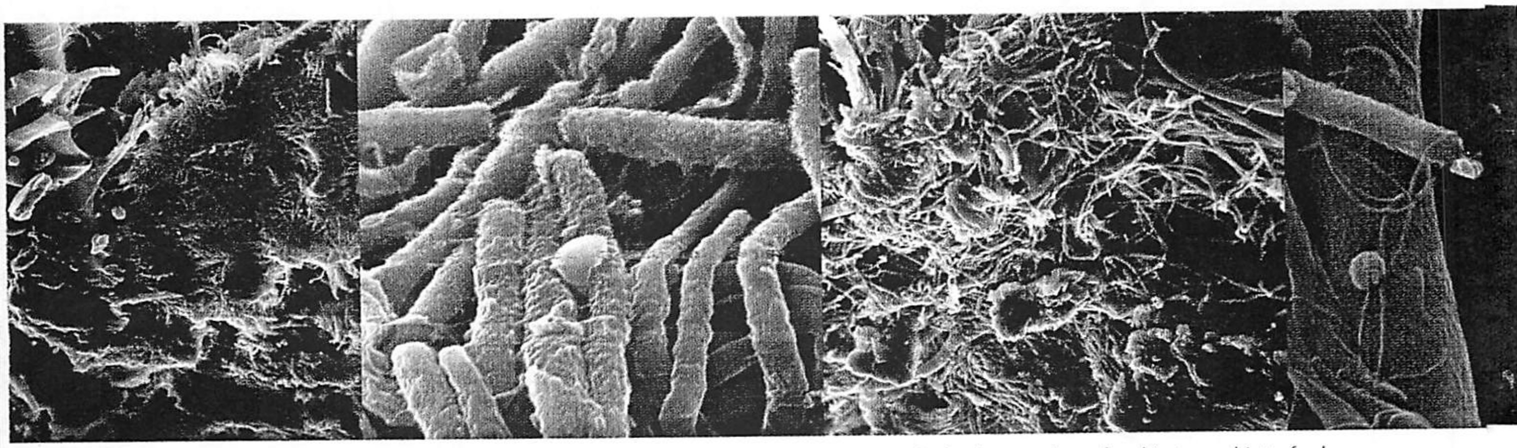
One afternoon I watched Warnecke dissect 50 of the new termites. He worked at a rapid clip, pulling the insects' heads and anuses in opposite directions with a microscopically violent yank; each termite's gut unwound into a short, lumpy string. He showed me an electron-micrograph image of the inside of the gut. It looked like an undulating carpet. On it were rod-shaped bacteria; Warnecke pointed out pimple-like structures on the sides of a few, which he thought might be the space-station-like giant proteins. He speculated that the proteins work something like a Swiss Army knife, holding an array of tool-like enzymes and catalysts outside the cell to grab pieces of wood and whittle away, allowing the cell to slurp up the sugars thus released. If this hypothesis is correct, the proteins could be a great fit for biofuel production, because those loose sugars could be fermented into ethanol.

But the magnified images were far from conclusive. Hugenholtz slumped in front of the screen and complained that he saw no wood in the gut—were the termites starving? He impatiently made a list of tests he wanted done. Hugenholtz is confident that the team will eventually figure out what the proteins do. "You really see the science flailing around blindly here—but then things crystallize out of the darkness," he told me.

One morning when I met Hugenholtz and Warnecke at a coffee shop, they began to riff on how the gut might work. "You get the feeling the microorganisms are more dominant than the termite. They must have a way to control the insect," Warnecke said. Hugenholtz interrupted, quoting a colleague: "Maybe the termite is just a fancy delivery system for the creatures in the gut." We tend to assume that the larger organism in a symbiotic relationship is in charge, but relationships like the one between the termite and the microbes involve constant two-way chemical communications. Even human beings, Hugenholtz said, are subconsciously eavesdropping on chemical conversations between the inhabitants of our guts; this leads us to crave, say, potato chips when our microbes want salt. His eyes fell warily on his coffee. "Do you think our stomach bacteria have trained us?"

History suggests that science follows its own timetable, often producing results long after the politicians who approved the funding have left office. Yet curiosity without the prospect of imminent practical application is something biotech investors are increasingly loath to pay for. When the *Nature* study began, Diversa was on the cutting edge of "ethical enzyme the fragments were programmed to make. They then tested those enzymes on cellulose, to see if they would attack it. Only the winners made it to sequencing. You might think of the Joint Genome Institute as a group of diligent librarians, studying every step along the way. In contrast, a Verenium senior researcher told me, the company takes a "Julia Child approach"—once it has thrown together the ingredients (like termite guts and cellulose), it turns its attention to the final product, with far less focus on the stages in between.

Much of the action takes place in a machine—a type of robot, really—called the GigaMatrix. Clad in steel, the GigaMatrix looks like a copier from the late 1980s, with two flat TV monitors on top and a door on the side. It can screen up to a million enzymes at a go, easily exceeding in a single day the lifetime performance of a human lab tech. The GigaMatrix and other machines took the 500 or so most interesting enzymes from the termite gut and narrowed them down to fewer than 100 with potentially practical applications. Those were then tested for



A MOLECULAR WRECKING YARD: Electron-micrograph images of the termite's third gut, where food is turned into fuel

bioprospecting"—searching the world for novel environments and enzymes. After merging with a biofuels company, it became Verenium last year, and shifted to the more prosaic task of making commercial enzymes involved in the development of products including animal feed, paper, and fuels.

David Weiner, the assistant director of enzyme technology at Verenium, gave me a tour of the labs, showing me what he calls the "giant funnel"—the process the company uses to sift through nature's intellectual property for enzymes that can be converted to profits. "We're not really interested in DNA," he said, meaning that the focus is on an enzyme's performance, not its origins.

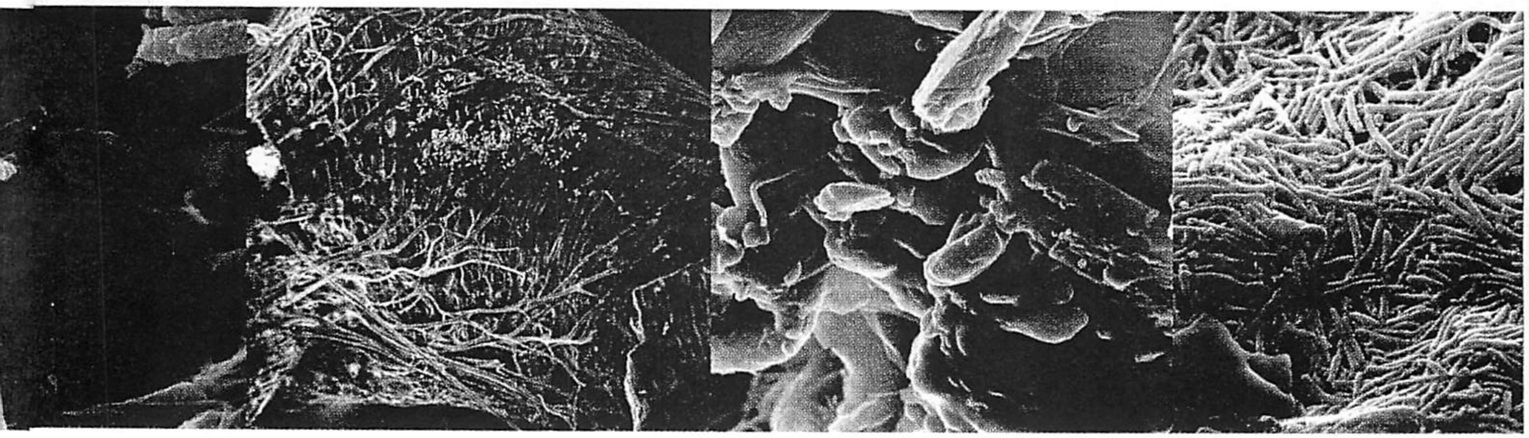
Whereas the Joint Genome Institute began by sequencing the termite-gut DNA—learning about its underlying structure—and only then tried to identify what might be useful, Weiner's colleagues threw all the material from the Costa Rican expedition directly into testing, using the funnel approach to separate the most-useful enzymes from the millions of useless ones. Researchers inserted gene fragments into lab bacteria that had been genetically "tamed" to produce whatever their effects on cellulose, modified, and inserted into "factory" bacteria trained to produce large quantities of enzymes while dining on cheap food, such as corn syrup. As the enzymes made their way through the process, every parameter of their growth and efficacy was measured. Only a small percentage proved powerful enough to merit continued investigation; these were stirred into multiple-enzyme "cocktails" to evaluate their speed and efficiency in combination. By the end, Weiner said, just a few enzymes remained in the running for further testing.

Geoff Hazlewood, a former senior vice president and now a consultant to Verenium, told me that the company has currently put aside studying termites for biofuels and has moved on to other potentially lucrative efforts. "You could screen ad nauseam," he said, "but you can't commit an infinite amount of resources." Whatever the termites are doing may be too complicated and fragile to be useful in a large industrial process. There may be genius in the termite gut—Weiner calls it, admiringly, "a whole town"—but the wonders of symbiosis, in themselves, mean little to companies focused on the bottom line. "We want faster, cheaper, more efficient," Weiner told me.

FALK WARNECKE, PHIL HUGENHOLTZ, DOE JOINT GENOME INSTITUTE; MANFRED AUER, UC BERKELEY AND LAWRENCE BERKELEY NATIONAL LABORATORY

And it's too early to tell whether the termite will *ever* provide genes or information that will enable biofuel production. Termite research could instead provide a cautionary tale about the difficulties of replicating nature on a political schedule. It may be faster and easier to come up with a comprehensive energy policy—investing in energy efficiency, changing personal behavior, and working with other large oil consumers to control prices—than to create a cellulose economy out of the termite gut.

Termites certainly have their critics. One is Harvey Blanch, a professor of chemical engineering at UC Berkeley and the chief science and technology officer at the Department of Energy's Joint Bio-Energy Institute, in Emeryville, California (where Hugenholtz also conducts research). "Those microbes eat pâté!" Blanch said. By the time wood reaches the termite's third gut, he explained, it has been chewed to a fine consistency and soaked in the highly alkaline second stomach; the gut microbes don't have to work very hard to break it down. Pre-



treating wood in similar ways on an industrial scale would be ridiculously expensive, he believes. He thinks the termite has been overhyped, and sees this as a reflection of unrealistically high hopes for quick, painless replacements for gasoline.

Blanch has experienced the pitfalls of research driven by political goals. In the early 1970s, he worked on creating faux meat products from petroleum, which was then thought to be a cheap way to feed the world. For example, single-celled "chicken" proteins were produced by yeasts that fed on oil byproducts, and then draped around plastic bones. But when the 1973 oil crisis hit, the cost of the raw material soared, effectively ending the petroprotein business. Blanch then shifted to cellulosic ethanol; the project was progressing until President Reagan killed it, in the mid-1980s. Now, he's at once hopeful that we will one day be able to engineer novel organisms and make better fuels, and wary of putting too much faith in quick technological solutions. "Given the scale at which we need to operate, it's hard to imagine any magic organism that will do the trick," he told me.

Several years ago, government labs set a goal of producing cellulosic ethanol for $1.33 a gallon by 2012, but Blanch cautions that the retail price could be $6 or $8 a gallon if the cost of the raw materials rises, and he thinks a realistic deadline is at least 10 years away. Perhaps because of his earlier experiences, he fears that projects that fail to deliver quickly are at risk, which puts a lot of pressure on both the Bioenergy Research Centers and individual researchers.

These concerns speak to an important tension underlying the termite research: the often competing agendas of work aimed at producing quick results, and of the slower, more methodical approach known as basic science, which tries to discover the fundamental logic of natural processes. Again, Julia Child (or maybe the more commercial Wolfgang Puck) versus the librarians. Some of the scientists—and even venture capitalists—I spoke with voiced fears that the race to harness nature for fuel production may cause us to neglect basic science and thus jeopardize potential long-term gains.

Consider this: half of the 80,000 genes inventoried from the Costa Rican termites remain unidentified, and each of those 40,000, Warnecke imagines, could require a Ph.D. thesis to figure out. Hugenholtz says that metagenomics is grappling with the problem of having too much information and too few references. "Sequencing is far outstripping our ability to characterize the genes," he explains, adding that this can lead to "genome rot"—a chain of errors created when one scientist gets a gene wrong, and then the mistake is multiplied across other genomes. The popular model of science is based on "eureka" moments, but right now, metagenomics is more like a big 3-D puzzle, where every new piece of knowledge—and every mistake—affects the whole. Trying to solve just one part of the puzzle for a quick commercial breakthrough may be as tricky as solving the entire thing.

It could also cause us to give short shrift to alternative solutions. Eric Mathur was one of the Diversa executives who helped set up the Costa Rican expedition; he now works for Synthetic Genomics, a company founded by the scientific impresario Craig Venter to search for biology-based fuels and methods to cut greenhouse-gas emissions. Mathur says the *Nature* paper is just

the beginning of a long process of understanding how symbiotic creatures deal with wood and carbon. He thinks that searching for individual enzymes in the termite will be a dead end, but that harnessing the power of whole environments might yield results. The challenge, he says, is to learn how these environments' overall metabolisms work, and then use the tools of synthetic biology to engineer the organisms in them to evolve—creating a "slave organism" that focuses all of its resources, down to its last electron, on processing carbon. "Metabolic engineering is a very powerful method for productivity," he told me.

But the strongest argument for more basic research may be the termite itself. Jared Leadbetter, an associate professor of environmental microbiology at Caltech, remembers feeling "like an ecotourist in *Alice in Wonderland*" the first time he looked at a magnified termite gut, 18 years ago. Leadbetter has pioneered the study of the metabolism of a few of the spirochetes in the gut. Like Mathur, he believes scientists might put the termite's gut to work against global warming by using it to understand and possibly alter the carbon cycle—the biogeochemical give-and-take of greenhouse gases between the Earth and its atmosphere.

Leadbetter says one of the extraordinary things about termites is not how much ethanol they might make, but how little methane they produce. Cows lose 20 percent of the energy in the grass they eat, because the microbes in their stomachs combine hydrogen and carbon dioxide from the grass to make methane, a greenhouse gas that traps 20 times as much heat in the atmosphere as CO_2. In 2006, the greenhouse gases produced by U.S. farm animals exceeded the emissions of the iron, steel, and cement industries combined. Termites lose less than 2 percent of their nutrients to methane production, because the spirochetes in their guts transform hydrogen and carbon dioxide into acetate, which the termites use as fuel. If we understood this process, perhaps we could put new microorganisms into the stomachs of cows and reduce their production of methane.

We're a long way from changing the chemistry of cows' stomachs, but the process of adapting and commercializing the termite's role in the carbon cycle has already yielded success on a small scale. The Virginia-based company ArcTech trained termites to eat coal, and then rummaged through their guts to find the microorganisms best at turning coal into methane. It cultured those microorganisms and now feeds them coal; the company plans to use the methane they produce to make electricity, and is already selling the by-products, including one used by farmers as a soil additive. ArcTech says this method eliminates virtually all greenhouse-gas emissions from coal-based electricity production. Other companies are trying to engineer similar organisms that could be sent into abandoned mines and oil wells to scavenge fuel that goes unused because it is so hard to get at. Such efforts could have a dramatic effect on both the environment and geopolitics: experts estimate that increasing the yield of oil wells from the current average of 35 percent of the oil in a reservoir to 40 percent would be the equivalent of discovering a new Saudi Arabia.

Who knows what other answers may lurk in the termite? Elizabeth Ottesen, a graduate student doing research in Leadbetter's lab, dissected a termite and put it under a microscope to give me a tour of its gut. At first glance, the dark mass of the gut was immobile, the organisms apparently packed too tightly to move, but as Ottesen added water, a menagerie of blobby *Trichonympha*, whizzing spirochetes, and other creatures materialized, all supported by gangs of bacteria too small to see. The inhabitants here are arranged in hierarchies more elaborate than Manhattan real estate, she said: Those at the edges use oxygen, while those in the middle are anaerobes. Many are high-speed commuters, outfitted with complicated sensing and swimming apparatus that helps them find hydrogen and other gases. Among the creatures in the termite's gut, and especially among those creatures' genes, exist redundancies that suggest the system has been overengineered to survive the worst (including being force-fed coal). A spirochete's flagella, for example, are between the layers of a double skin, enabling the organism to drill through the most viscous environments.

Leadbetter expects it will take at least 25 years to unravel what he calls the "teleological questions" about the termite's complexity. Along the way, the termite will likely provide clues to solving climate change, but Leadbetter thinks its greatest value may be as a repository of biological wisdom gathered over the course of more than 100 million years of survival on Earth. "When you look at a termite and its gut," he says, "you're looking at a long line of winners."

Lisa Margonelli is an Irvine Fellow at the New America Foundation and the author of Oil on the Brain: Petroleum's Long, Strange Trip to Your Tank (2007).

QUAI AUX FLEURS

I want to just keep on smearing butter
& jam on toast with a blunt knife
and licking foam from my espresso cup,
while listening to Lizzy and Tricia practice French,
but I'm a realist. Even the songbirds have levels
of mercury in their blood and feathers. Somewhere,
in the brightness against a wall, a soldier crouches—
sand in his hair, juices dripping from his body.
Here there is joy, like a hole with greenness coming
out of it, but there night pushes against the cylinder
of his gun. He probably has a knife too, in the presence
of the incomprehensible, thrusting his belly
to the ground, feeling the strangeness throb in his blood
as he touches the scope to his cheek.

—HENRI COLE

Henri Cole is the author of six collections of poetry, including Blackbird and Wolf (2007). He teaches at Ohio State University.

AE-105

Purdue University

Cooperative Extension Service

West Lafayette, IN 47907

Methane Generation From Livestock Waste

Don D. Jones, John C. Nye and Alvin C. Dale
Department of Agricultural Engineering
Purdue University

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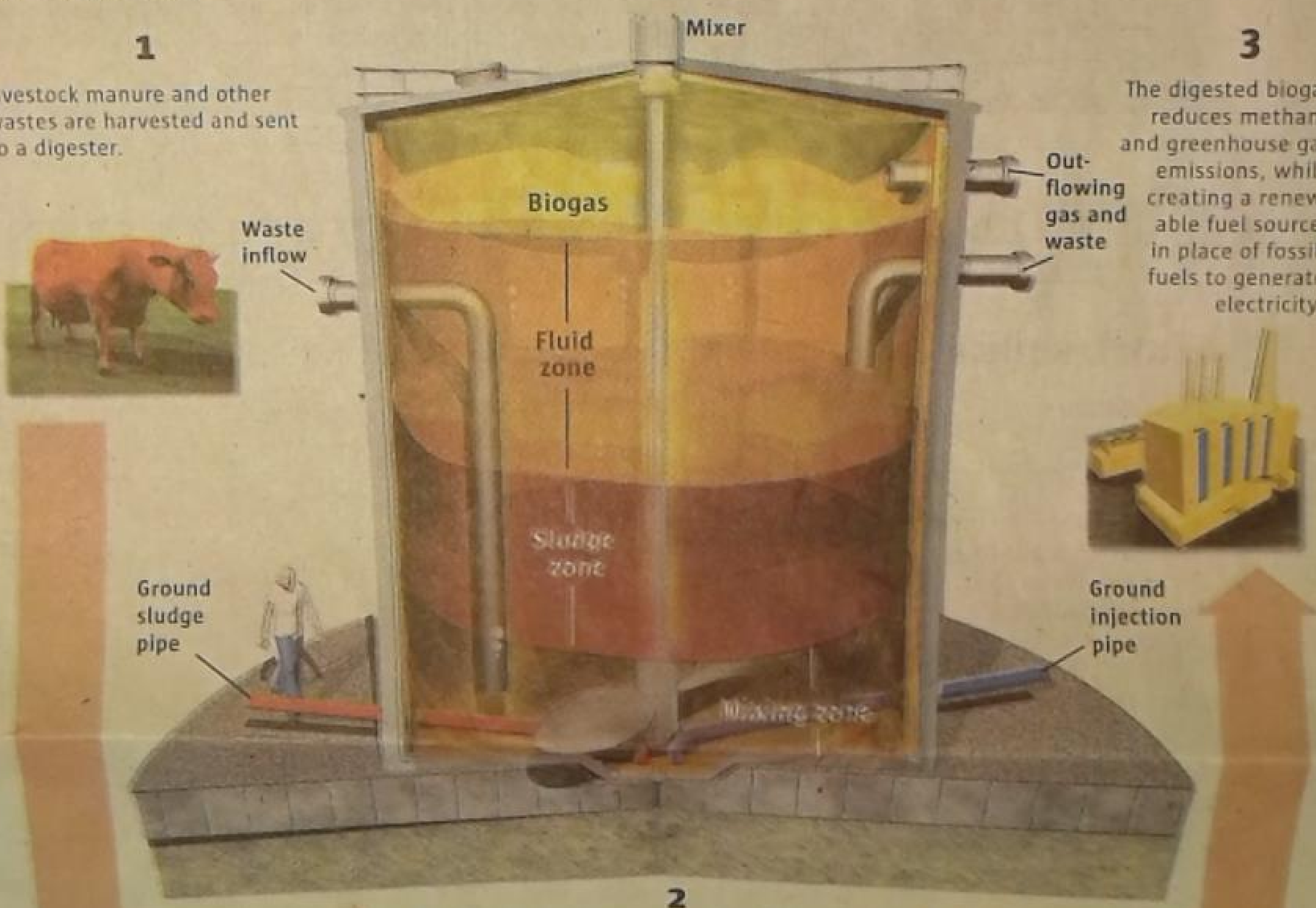
Waste electricity

Cow manure and other wastes are the key to producing renewable natural gas that will supply fuel to Xcel Energy's Fort St. Vrain power plant near Platteville.

1
Livestock manure and other wastes are harvested and sent to a digester.

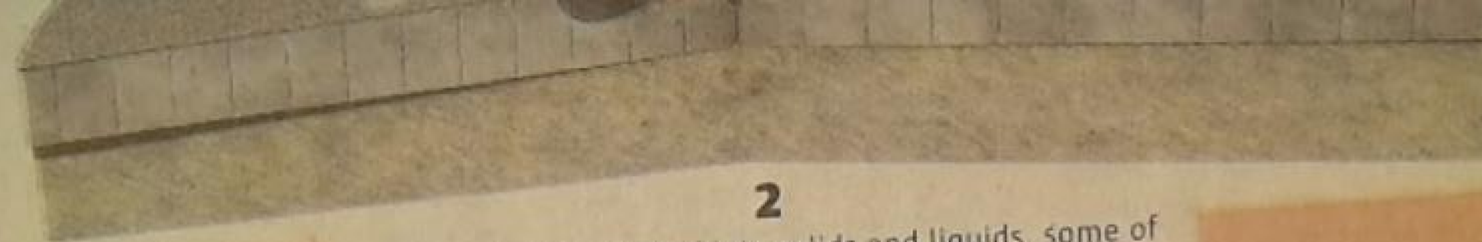
3
The digested biogas reduces methane and greenhouse gas emissions, while creating a renewable fuel source in place of fossil fuels to generate electricity.



2
The waste is separated into solids and liquids, some of which are recycled. The remaining organic material is converted to carbon dioxide and methane gas, also known as biogas. The biogas is transported to power plants by pipeline.

Source: Environmental Power Corp.

Jonathan Moreno, The Denver Post



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Source: Environmental Power Corp.

Jonathan Moreno, The Denver Post

By Steve Raabe *The Denver Post*

Cows reliably produce two things. One is milk. The other soon will become a source of your electric power.

Cattle manure meets the New Energy Economy next year when a New York firm plans to build the nation's largest plant for converting livestock waste into fuel — methane gas — for generating electricity.

Xcel Energy has agreed to buy the gas for its Fort St. Vrain power plant near Platteville.

The $30 million "biogas" facility will be built at a site not yet chosen in Weld County.

The concept is not new. Several livestock feeding and dairy operations in Colorado have methane-collection systems fueling small, on-site power generators.

But the plant being developed by Tarrytown, N.Y.-based Environmental Power Corp. will be much larger than any similar system in Colorado.

The facility's 12 silo-shaped anaerobic digesters will produce enough methane to power 17,000 Colorado homes, the company said.

Although the methane will replace just 3 percent of Fort St. Vrain's regular natural-gas consumption, it will help toward a mandate that Colorado utilities produce 20 percent of their power from renewable sources by 2020.

"There's great potential for using biogas," said Stacey Simms, a biofuels expert with the Colorado Governor's Energy Office. "Anaerobic digestion makes a lot of sense and can be an important source of renewable energy. It's a good fit for utilities."

The technology is simple: Manure and other organic waste emit methane as they decompose. The biogas facility will collect the gas, clean it and ship it to Fort St. Vrain via pipeline.

At the power plant, natural gas — whether from conventional underground sources or manure-derived methane — is ignited. The resulting hot gas spins jet-engine-like turbines that produce electricity.

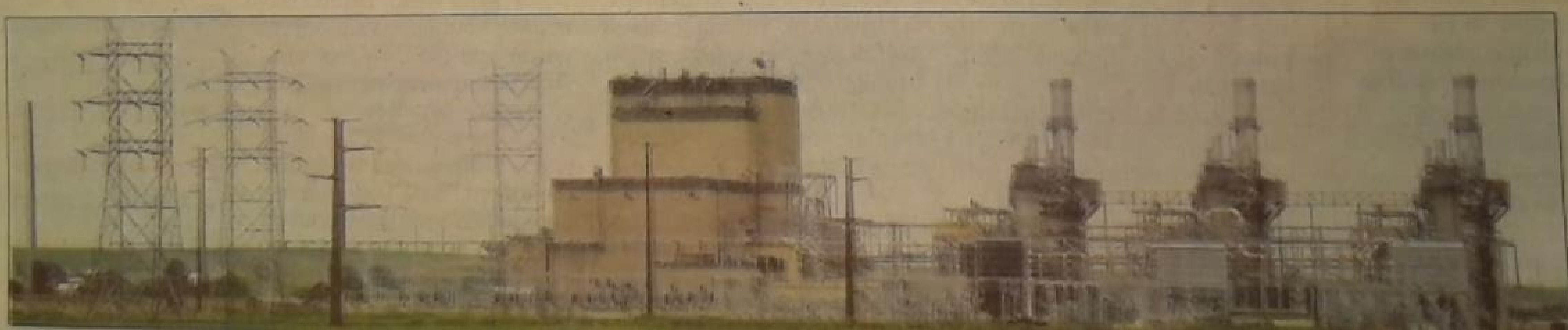
Fort St. Vrain was built in the 1970s as a nuclear power plant, but it was decommissioned after a series of technical problems and later converted to gas power.

Microgy, a subsidiary of Environmental Power, has patented a process that it says is more efficient because it can use a variety of organic wastes. In addition to manure, it can use food-processing byproducts and wastes from carcass-rendering plants.

Microgy has some small-scale digesters in Wisconsin and a larger facility in central Texas from which the methane it produces is sold to Pacific Gas & Electric in California.

Xcel's deal calls for the utility to pay Microgy a premium over market prices for conventional natural gas.

Steve Raabe: 303-954-1948 or sraabe@denverpost.com



Silencing the Lambs: Scientists Target Sheep Belching to Cut Methane

* * *

Reducing Gas in Livestock Could Help World Breathe Sigh of Relief Over Global Warming

WSJ 26Feb09/A1

BY PATRICK BARTA

PALMERSTON NORTH, New Zealand—On a typical day, researchers in this college town coax hungry sheep into metal carts. They wheel the fluffy beasts into sealed chambers and feed them grass, then wait for them to burp.

The exercise is part of a global effort to keep sheep, deer, cows and other livestock from belching methane when they eat and regurgitate grass. Methane is among the most potent greenhouse gases, and researchers now believe livestock industries are a major contributor to climate change, responsible for more greenhouse-gas emissions than cars are, according to the United Nations.

New Zealand sheep

Plenty of people, includin
farmers, think the problem c
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But governments are coming ur
der pressure to put a cork in i
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sumers to stop buying
meat and thus slow cli
mate change.

All of which is breathing new life into the study of sheep stomachs. Researchers have tried just about everything, from changing the animals' diets to breeding new sheep they hope will be less gassy. They've concocted

Please turn to page A9

Silencing the Lambs: Methane

Patrick Barta/The Wall Street Journal

Left to right, researchers rustle up sheep behind the lab in Palmerston North, New Zealand, then place them

Continued from Page One

cocktails of clover, garlic and cottonseed oil to try to curb methane. They have even tried feeding the animals chloroform, which can stymie the production of gas if it doesn't kill the animal.

But sure as grass grows, livestock keep producing methane.

"We're at a very theoretical stage," says Simone Hoskin, a livestock expert from Massey University, an institution involved in the research going on in this grassy New Zealand town. "A lot of people think we are insane."

There was an earlier golden age of sheep stomach research—in the 1950s, '60s and '70s. In those days, governments were looking for ways to improve animal digestion so livestock could produce more food for a hungry planet.

But as worries over food supplies waned, research tailed off. Scientists, as it happened, weren't all that thrilled about fishing around in animals' stomachs, which can contain up to 150 pounds of mushy meadow grass. "The stuff smells in a way you can't imagine," Ms. Hoskin says. "It really stays on you."

The root of the problem is that sheep, cows, goats and other so-called ruminants are unique in the way they digest their food. While that allows them to convert more energy from grasses, the process also generates hydrogen as a byproduct. Microbes known as methanogens convert the hydrogen to methane, which then leaves the animal through belching—and to a lesser extent, flatulence—and then floats into the atmosphere, where it helps to trap heat and potentially accelerate global warming. Humans emit methane, too, but not so much.

As awareness of the issue has grown, the U.S., U.K. and other countries have stepped up their research. But "there is no question that New Zealanders lead the world," says John Wallace, a scientist at the Rowett Institute of Nutrition and Health at the University of Aberdeen in Scotland.

That's partly because New Zealand prides itself on its environmental conscience. It is also, Kiwis say, from necessity: Their otherwise clean island is home to about 35 million sheep nearly 10 times the human pop lation—and millions of cow deer and goats.

As a result, roughly 48% New Zealand's greenhouse gas come from agriculture, co pared with less than 10% in su large, developed economies the U.S. Agricultural leaders fe their livestock-heavy econon could be at risk if there's an inte national move to tighten rul on animal emissions.

Kiwis tried to get a leg up the problem in 2003, when poli cians proposed an emissions t on livestock. Farmers thoug they were getting fleeced and a tacked what they called a "fa tax." The idea was tabled.

But livestock owners and sc entists knew the issue wasn't g ing away. With the help of indu try groups such as Meat & Wo New Zealand, they put up mi lions of dollars to finance a wa on sheep emissions.

The group, the Pastora Greenhouse Gas Research Co sortium, helped assemble em nent animal-stomach exper from around the world. They i

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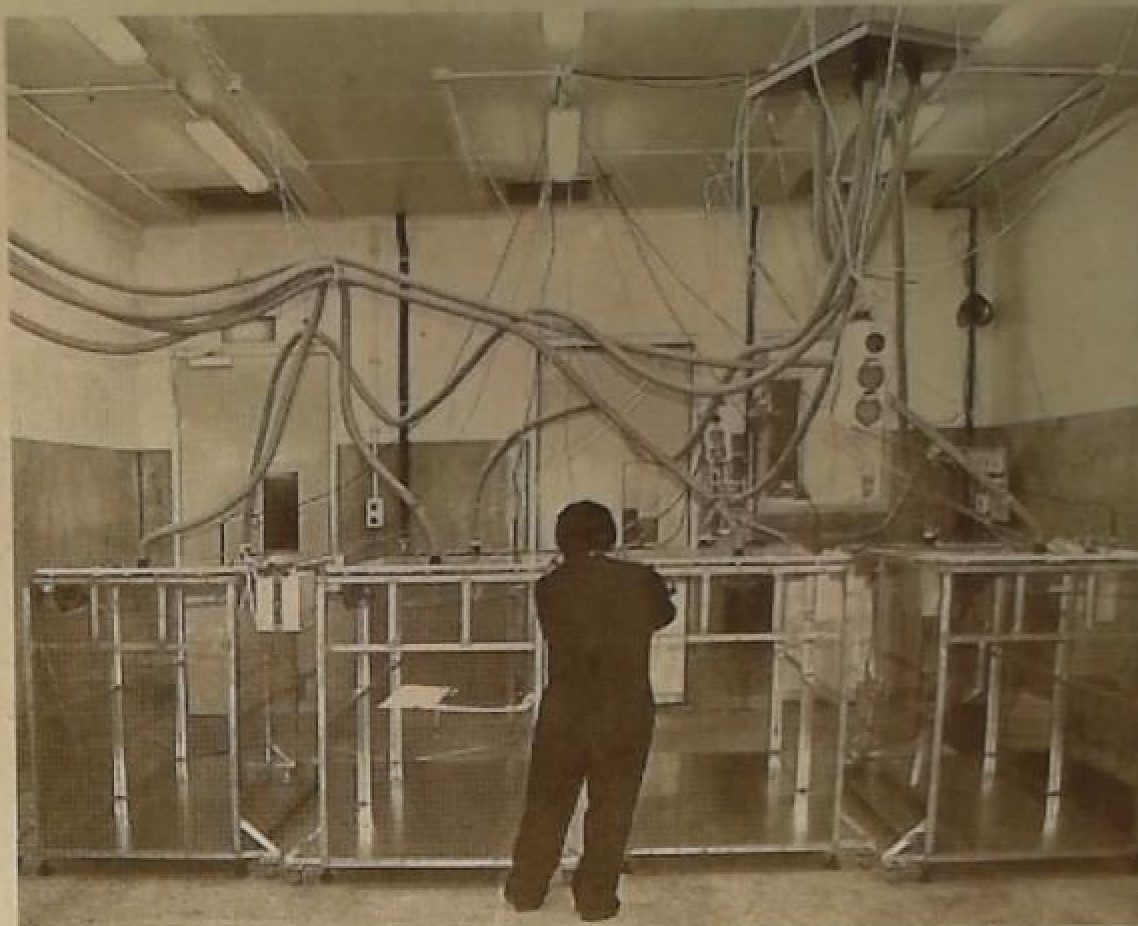

...ce them in a cart to be wheeled into sealed chambers to measure levels of the greenhouse gas methane the animals burp up.

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cluded Ms. Hoskin, who had spent much of her career working on such topics as the role of leafy turnips in deer grazing. It also included itinerant ruminant researchers from the U.K., Germany, Peru and Sri Lanka.

Much of the work occurs here in Palmerston North, a town north of Wellington surrounded by rolling hills and filled with some of the most sophisticated animal-emissions gizmos in the world. Chief among them: 10 "respiration chambers," which scientists use to measure burps under different experimental conditions.

Pumps circulate fresh air into the chambers. Researchers rustle up an animal—often a sheep—from behind a laboratory, and then wheel it into the chamber, where the bleating creature munches on grass. The concentration of methane in the air then usually increases. The cud chewer is oblivious.

"They love it here," says Cesar Pinares-Patino, a Peruvian scientist who helps run the chambers. The animals "can look at each other and be comfortable." Sometimes they stay in the chambers for days, he says.

The boxes help show what strategies are working. But scientists haven't achieved a breakthrough. Many of the dietary additives known to reduce methane—cottonseed oil, for instance—don't work well in the long run; sometimes they cost too much or the animals don't digest them well. Chloroform additives worked for a while, but the animals' stomachs adapted and started emitting again.

Researchers are particularly proud of one achievement, though: Using genome sequencing to draw a genetic map of one of the leading methanogens. Team members passed around a single-malt whisky when they finished that work in June. They say the breakthrough should make it easier to identify compounds that can attack the methanogens so methane isn't made in the first place.

"We now know our enemy," says Peter Janssen, a scientist who worked in Germany and Australia before returning to his native New Zealand two years ago to do livestock emissions research.

Some farmers elsewhere in the world are bemused. "I applaud them" for trying, says Eric Davis, a cattleman whose operation in Bruneau, Idaho, has more than a thousand head of cattle, and hence plenty of gas. But "I'm skeptical they'll come up with anything we can practically use," he says. Besides, "I still have a problem with whether methane is a problem."

Mr. Janssen admits his work would probably be "fringe science" if it weren't for all the interest in climate change. But he still thinks it will generate something useful.

"It could be two years, or it could be 20" before a solution to animal burps is found, he says. But someday, "it will suddenly show up. And then you will have it."

WSJ.com

ONLINE TODAY: See how researchers in New Zealand are trying to put a lid on the methane produced by grazing sheep, at **WSJ.com/Video**

Methane from manure fuels et

Across the country, eco-friendly ethanol plants that burn methane instead of costly natural gas or coal are in the works.

D.P. 29/Jan 07 -16

By Nate Jenkins
The Associated Press

Mead, Neb. — Ranchers have long been fond of saying cattle manure smells like money.

Now, folks in the business of making ethanol are smelling dollars too — in the methane gas emitted by manure at large cattle feedlots and dairies.

Across the country, ethanol plants powered by methane instead of costly natural gas or coal are on the drawing board — a movement that could be a win-win situation for the environment and the industry.

"We'll produce ethanol much more efficiently and do it in an environmentally friendly way," said Dennis Langley, CEO of Kansas-based E3 BioFuels.

Burning the methane will cut the amount of the greenhouse gas — which contributes to global warming — released into the environment.

And in addition to providing a cheap energy alternative, using methane addresses a longtime criticism that making ethanol uses too much natural gas or coal.

Supporters of corn-based ethanol and other biofuels contend they burn cleaner than fossil fuels, reduce U.S. dependenc foreign oil and give farmers other market to sell their duce.

The first plant using so-called methanol closed-l system is set to begin operati here in February.

Under the closed-loop sys at the Mead plant, manure fall through metal slats in the tle pens and be collected. Me ane from the manure will trapped instead of being allow to drift into the atmosphere, then used to generate power the plant.

Corn and grain will be used produce ethanol, and cattle w eat the wet distiller's grain th is a byproduct of ethanol produ tion, closing the loop.

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Langley's plant is next to a 28,000-head cattle feedlot. The cattle will produce 244,000 tons of manure annually — more than enough to be the sole power source for the company's 25-million-gallon ethanol plant.

If the plant and others like it are successful, they could begin increasing expectations about the environmental impact of alternative-fuel production.

"Cows are a major source of greenhouse gas," said David Mager, vice president of Bion Environmental Technologies, a company helping livestock operations incorporate ethanol production by using manure. The company is working with five ethanol plants now. "One-third of all methane comes from livestock."

Langley's company has a goal of completing 15 such plants over the next five years.

Other companies have similar plans to use methane to power ethanol plants.

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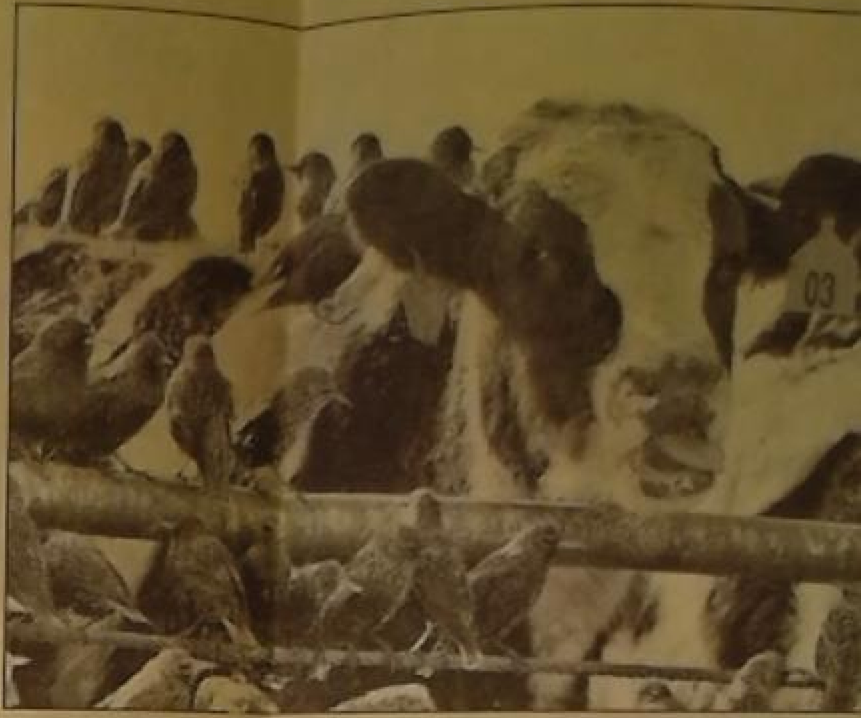

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Nati Harnik | The Associated Press

A feedlot in Mead, Neb., will provide methane to power an ethanol plant that is scheduled to begin operations in February.

Langley's company has a goal of completing 15 such plants over the next five years.

Other companies have similar plans to use methane to power ethanol plants.

Texas-based Panda Ethanol plans to build a total of four methane-powered ethanol plants in Texas, Colorado and Kansas, with the first scheduled to begin operations late this year.

Seafaring Scientist Sees Rich Promise In Tiny Organisms

WSJ 13 Mar 07 B1

By Gautam Naik

Marine microbes are among the most abundant life form on the planet and among the most mysterious. Now, results from the first phase of a global expedition are expected to provide a glimpse into this long-hidden world while potentially leading to new drugs and even fighting climate change.

Craig Venter, the brash biologist who helped crack the human genome seven years ago, says he and other scientists have used DNA-analysis techniques to discover millions of new genes and thousands of new proteins in ocean microbes. These microscopic life forms are mainly bacteria and organisms known as archaea.

"Everything we've seen is a surprise," Mr. Venter said in a phone interview from his marine research vessel, Sorcerer II, in the Sea of Cortez. The unexpected variety of microbial DNA he's found overturns earlier notions that the oceans are a homogenous soup of bacteria and other microscopic life. The details are being published today in the Public Library of Science Biology, an Internet-based scientific journal.

A diverse supply of microbial DNA from the oceans could be a rich lode for scientists. Drug companies are hunting for new compounds in sea creatures, especially to attack cancer and neurodegenerative diseases. The new data will also allow researchers to compare the DNA of oceanic bacteria to the genetic code of microorganisms that cause human disease.

"This is the largest DNA sequence ever obtained, and the magnitude of what's being done is entirely unparalleled," said Douglas Bartlett, professor of marine microbiology at the University of California, San Diego, who isn't involved in Dr. Venter's project. Marine microbes "have all kind of metabolic activity. It is expected that [Dr. Venter's team] will discover new pathways for making drugs and treating infectious disease."

Dr. Venter, one of the more savvy scientists

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Seafaring Scientist Hunt

Continued from page B1

when it comes to publicity, likens his project to Charles Darwin's 19th-century voyage on the Beagle. The journey is also modeled on one of the first oceanographic expeditions, by the British sailing ship Challenger in the 1870s, which sought to determine whether there was life in the ocean depths. The findings filled 50 volumes, each as thick as a family Bible. Similarly, the data from the first phase of the Sorcerer expedition is expected to be the largest such troves of genetic information released in the public domain.

J. Craig Venter Institute

Craig Venter's **Sorcerer II**, on its expedition to find and study microbes.

The ocean project "is adding new genes to our tool kit," said Dr. Venter, 60 years old. "They are key to the next phase of biology: the synthetic phase."

Dr. Venter is betting the findings could also pave the way to alternative energy. By adding genes from sea organisms, he speculates, microbes created in the lab may be engineered to release hydrogen, an alternative fuel. Another idea would be for such microbes to absorb excess carbon dioxide and reduce the impact of climate change.

In labs run by the J. Craig Venter Institute in Rockville, Md., one such experiment is already under way: an attempt to alter the process of photosynthesis and produce hydrogen gas. The target is hydrogenase, a small bacterial protein system that produces hydrogen and is also highly sensitive to oxygen. Dr. Venter says his team found a hydrogenase by sequencing the genes of microbes fished from the Sargasso Sea, and it is far less sensitive to the presence of oxygen. His team hopes to make a microbe with a synthetic version of that gene and thereby produce hydrogen gas in room air, which is about 21% oxygen.

The Sorcerer II expedition started with a pilot project in 2003 in the Sargasso Sea near Bermuda. In an area believed to have little microbial diversity, the team discovered a million new genes and 150 new species of bacteria. The project then became more ambitious, seeking to obtain microbial DNA from the world's oceans in a two-year circumnavigation that cost $10 million, ending in December. It then continued sampling waters of the Northern Hemisphere. The U.S. Department of Energy and the Gordon and Betty Moore Foundation funded the sequencing and analysis, while the Venter institute funded operation of the Sorcerer.

The team obtains samples with two 52-gallon buckets every 200 miles or so. The water is passed through four sets of filters, and the remaining microorganisms are sent to the Maryland labs, where their DNA codes are sequenced.

Scientist Hunts Microbes

J. Craig Venter Institute

Craig Venter's **Sorcerer II**, on its expedition to find and study microbes.

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Unexpected problems cropped up during the expedition. The research falls under the jurisdiction of a United Nations convention on biological diversity, which requires the Venter team to obtain permission from countries before obtaining microorganisms from territorial waters. Even though the invisible ocean-going microbes know no boundaries, they are deemed to be the "genetic patrimony" of that particular country. One dispute over who had such rights resulted in Dr. Venter's team being placed under temporary "house arrest" in French Polynesia, Dr. Venter says.

In the late 1990s, Dr. Venter, through his company Celera Genomics, launched a private effort to sequence the human genome, famously challenging a rival effort financed by the U.S. government—and concluding in a history-making tie. His idea to sell tools and resources related to the genomic database for a fee never took off.

Dr. Venter was fired by Celera in early 2002 over squabbles with the board about the company's direction. He then embarked on a bid to create artificial life forms in the lab and plan the Sorcerer trip.

Data will be available via a massive, online publicly accessible database funded by a seven-year, $24.5 million grant, Dr. Venter said.

Climate Change: Garbage Gets Fresh Look as Source of Energy

WSJ 15 may 09/A9

Jeffrey Ball for The Wall Street Journal

Covanta's Hempstead, N.Y., plant burns nearly a million tons of trash a year.

HEMPSTEAD, N.Y.—Times change, and yesterday's environmental problem starts to look like today's solution. That is what is happening with trash.

Over the past two decades, the U.S. has shut down hundreds of pollution-spewing waste incinerators on the belief that burning detritus was a bigger environmental sin than burying it. Today, most American garbage is sent to landfills, some spanning hundreds of acres miles from the cities that generate the refuse. New York City, which tosses about eight million tons of nonindustrial trash each year, trucks much of it to big landfills in states such as Virginia and Pennsylvania.

POWER SHIFT

By Jeffrey Ball

Landfills have been convenient. But they are falling out of favor as improved technology and changing environmental priorities start to upend the old thinking about garbage.

Past orthodoxy held that burning trash was bad because it spewed toxic substances into the air. In an era when the big environmental threat was localized pollution like smog and cancer-causing plumes, landfills seemed the lesser evil.

Dirty air is still a concern, but now it has been eclipsed by fears of global climate change. In that calculus of environmental harm, recent research suggests, burning trash is better than burying it.

...tured and used to generate electricity. But a recent study by U.S. Environmental Protection Agency researchers said that most landfills fail to capture all of their methane, a potent greenhouse gas. The study concluded that incinerating a ton of trash emits at least 35% less greenhouse gas and yields 10 times as much electricity as burying it.

Old incinerators were infamous polluters. They coughed out large quantities of soot, the components of acid rain and carcinogenic dioxins.

John Waffenschmidt, a 53-year-old New Yorker who is a vice president for Covanta Energy Corp., the country's biggest owner of waste-to-energy plants, recalls delivering newspapers as a boy in the city in the 1960s. "I'd go out in the morning and there would be little flakes coming down," he says, "because there were 4,000 or 5,000 apartment-building incinerators."

The energy crisis of the late 1970s prompted a push for plants that burned trash to

door to a strip mall. Its 39-story steam tower is the tallest structure on Long Island.

Trucks carrying trash from Long Island and New York City roll into a cavernous room in the plant at a rate of about one every five minutes. The trash is pushed into another room, the "pit," where a crane operator tosses it around with a nine-ton steel claw. He is "fluffing" the rubbish—mixing in air to help it burn.

After being fluffed, the trash moves by conveyor belt into furnaces, where it is incinerated at about 2,000 degrees Fahrenheit, creating the heat that is used to generate electricity.

Today's incinerators are markedly cleaner than their predecessors, yet they still pollute. "One percent of a very toxic substance is still a very toxic substance," says Marchant Wentworth, a renewable-energy campaigner with the Union of Concerned Scientists, an environmental group.

Trash disposal of any sort is problematic. Ideally, society

Ball

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Dirty air is still a concern, but now it has been eclipsed by fears of global climate change. In that calculus of environmental harm, recent research suggests, burning trash is better than burying it.

The appeal of most modern incinerators is that they don't only torch trash. They also use the heat from the incineration to boil water, which creates steam, which in turn generates electricity. Yet trash incineration produces just 0.4% of the country's electricity. Even if all U.S. garbage were burned, it wouldn't produce anywhere near enough power to meet the country's energy needs. But as concern about climate change grows, any renewable source of energy—even a pile of garbage—seems appealing.

Landfills, too, produce potential fuel—in the form of methane, which can be cap-

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The energy crisis of the late 1970s prompted a push for plants that burned trash to make electricity. Today, 87 waste-to-energy plants are operating in the U.S., with the biggest clusters in Florida, New York and Minnesota.

Some 13% of U.S. garbage is burned—far less than the 54% buried in landfills and the 33% that is recycled. The modern plants turn prodigious piles of trash into ash yet often sit in the middle of heavily populated areas. New York's Long Island has four incinerators, one of the densest concentrations in the country. Its biggest, a Covanta plant in the town of Hempstead, burns 950,000 tons of garbage a year, right next

erated at about 2,000 degrees Fahrenheit, creating the heat that is used to generate electricity.

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Trash disposal of any sort is problematic. Ideally, society would produce less trash. Recycling is the next-best option.

In Congress and in many state capitals, lawmakers are considering whether to endorse trash incineration as a "renewable" source of power. A green imprimatur would be a boon to the trash-burning industry, which is lobbying feverishly for the move.

Covanta's Hempstead, N.Y., incinerator is applying for permission to expand and burn more trash. Meanwhile, Long Island's main highways, like the roads leading out of New York City, are filled with trucks ferrying the rest of the area's garbage to landfills in other states.

How electricity is produced from cows

Collecting methane gas from landfills to run gas engines that generate electricity is an effective way to reduce greenhouse gas emissions. Any methane released from a landfill and not burned in a gas engine has 21 times the greenhouse gas potency of CO_2 produced by the engine itself. In addition, use of landfill gas is a substitute for other resources such as coal, oil or natural gas to produce the same amount of electricity.

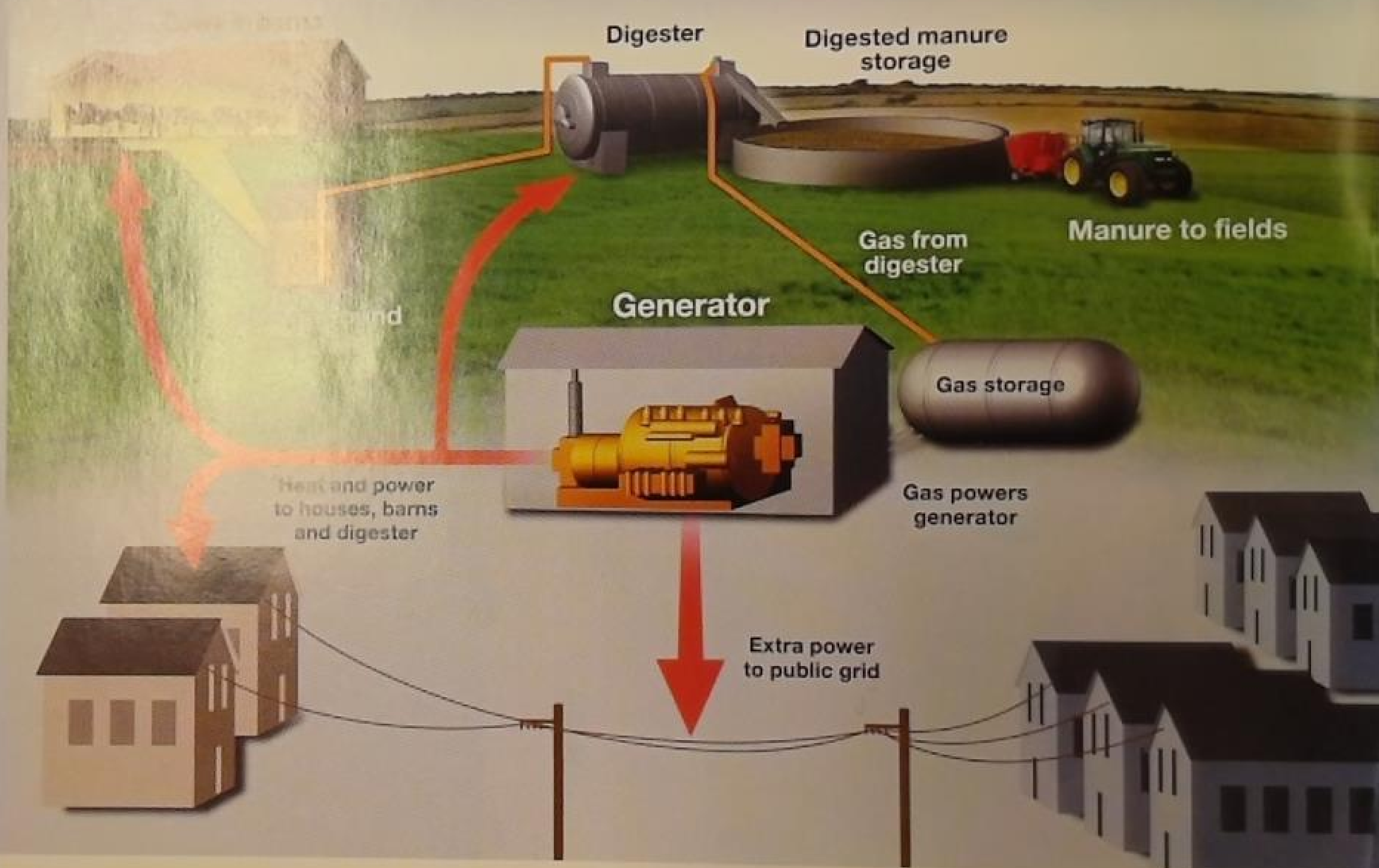

Illustration by Patrick Gabriel

The Lamp 2007 No 4
ExxonMobil

The *Mobil Pegasus* line of industrial lubricants is specifically developed for natural-gas and biogas engine operations. Products include *Mobil Pegasus 1*, a fully synthetic formulation designed for operation in

especially challenging landfill gas-engine applications.

All products in the *Pegasus* line are aimed at lowering operating costs and boosting productivity. "It's about improving customers' productivity so they are more

…oil or natural gas to produce the same amount of electricity.

Illustration by Patrick Gabriel

The Lamp 2007 No 4
ExxonMobil

Photo by Brad Prickett

Dennis Haubenschild uses his farm cows, a generator and *Mobil Pegasus* 605 lubricating oil to produce electricity for his farm and other homes in Princeton, Minnesota.

▶ To learn more
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mobilindustrial.com/pegasus

The *Mobil Pegasus* line of industrial lubricants is specifically developed for natural-gas and biogas engine operations. Products include *Mobil Pegasus 1*, a fully synthetic formulation designed for operation in extreme ambient temperatures.

Recently, ExxonMobil launched *Mobil Pegasus 1005*, its "next-generation" premium natural-gas engine oil. *Mobil Pegasus 1005* was field-tested for more than 40,000 hours in engines around the world and has been shown to last up to twice as long as previous offerings on the market. This means potentially fewer oil changes and longer service intervals. *Mobil Pegasus 1005* has a unique chemistry that improves the cleanliness of engines and helps reduce deposits to minimize engine downtime. The company also launched *Mobil Pegasus SR* last year for especially challenging landfill gas-engine applications.

All products in the *Pegasus* line are aimed at lowering operating costs and boosting productivity. "It's about improving customers' productivity so they are more competitive in their marketplace," says Page. "Mobil industrial lubricants products are developed with that objective in mind."

Define, develop, deploy

While performance is paramount, these products face a broader challenge than simply meeting basic specifications. ExxonMobil's flagship lubricants are developed with "step-out" opportunities in mind – opening doors to carry the product line to the next level of performance.

Opportunities are formulated by studying market and industry trends identified by the company's strategic global accounts,