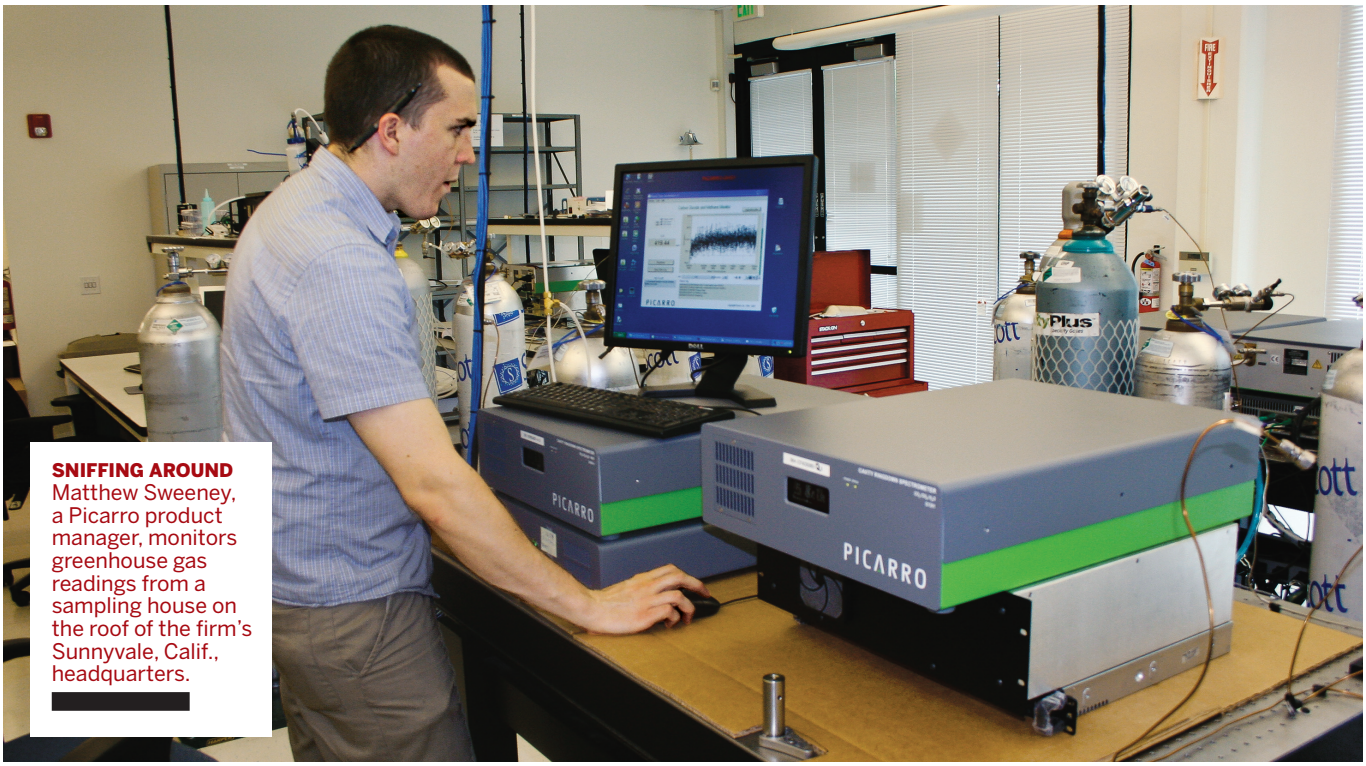
PICARRO



SNIFFING AROUND Matthew Sweeney, a Picarro product manager, monitors greenhouse gas readings from a sampling house on the roof of the firm's Sunnyvale, Calif., headquarters.

MONITORING GREENHOUSE GASES

Academia and government are avid purchasers of greenhouse gas **MEASUREMENT TOOLS,** but industry is slow to catch on

MARC S. REISCH, C&EN NORTHEAST NEWS BUREAU

BEGINNING NEXT YEAR, the Environmental Protection Agency will require U.S. operators of large carbon-emitting operations such as refineries, chemical facilities, and cement plants to submit annual emissions reports for carbon dioxide, methane, nitrous oxide, and other greenhouse gases (GHGs). But companies face a dilemma on how they will gather the data. Broadly speaking, they can choose between GHG-monitoring instruments and software that generates estimates based on energy consumption. Given the regulatory uncertainty of GHG regulation, most firms are in a quandary over the best way to proceed.

The global market for instruments that monitor industrial stack emissions is hard to put a finger on. The only estimate C&EN found comes from Michael Nemergut, vice president and general manager of air quality at instrument maker Thermo Fisher Scientific. He sets the global market at $700 million, which includes monitors of acid rain precursors, pollutants such as lead and ozone, and GHGs.

GHG instruments currently have only a thin slice of that $700 million market, but they are "a sizable opportunity," Nemergut says. Since EPA issued the emissions inventory rule in October 2009, "we've seen a pickup in CO_2 sensor sales, but we can't directly link those sales to the rule," he says. But for now, he adds, "it is fair to say that GHG monitoring is a small but growing segment of the market."

Government and academic markets for GHG-monitoring equipment, in contrast, are blossoming. Larry Middendorf, senior vice president of Li-Cor Biosciences, estimates that instrument makers sell several thousand high-precision GHG monitors per year. Based in Lincoln, Neb., Li-Cor sells portable infrared spectrophotometers that are widely used by scientists to study carbon dioxide and methane. "We're looking for tangential market expansion opportunities" in industrial markets, Middendorf says.

Regulatory restrictions on GHG emissions could catalyze new sales, but when those restrictions will come is uncertain. Congressional leaders have been unable to agree on a bill to tax GHGs (C&EN, Aug. 2, page 12), and questions remain about

"Running a plant efficiently is the best way to reduce greenhouse gases."

whether, when, or how EPA will act to restrict industrial emissions of GHGs. EPA Administrator Lisa P. Jackson has said the agency will issue regulations to restrict carbon dioxide and other GHGs at certain facilities beginning in 2011, but some Congress members have vowed to block Jackson's authority (C&EN, March 1, page 14).

IN THE MEANTIME, government urgency to document the sources of GHGs has led to an outpouring of funds to purchase new scientific instruments and to a plethora of data-gathering missions. This past December, for example, the National Aeronautics & Space Administration's Jet Propulsion Laboratory at California Institute of Technology began releasing data that show daily and monthly measurements of the concentration and distribution of carbon dioxide at 3 to 7 miles above Earth's surface.

These measurements come from the Atmospheric Infrared Sounder (AIRS), an instrument that the lab built in 2001 at a cost of $196 million to measure GHG concentrations in the upper atmosphere. Launched in May 2002 on NASA's *Aqua* spacecraft with other weather and atmospheric measurement instruments, AIRS is now sending data back to Earth.

Validating the AIRS readings took time and additional instrumentation and academic expertise. Government funds financed the Total Carbon Column Observing Network (TCCON), which consists of about 20 ground sites around the world that use Fourier transform infrared (FTIR) spectrometers to validate the space-based observations of AIRS.

A spokesman for instrument maker Bruker says some of the firm's FTIR instruments are being used at TCCON sites, many of which are also associated with a larger organization of 70 sensing stations around the globe, known as the Network for the Detection of Atmospheric Composition Change. Members of this network employ a host of sensing tools, including microwave radiometers, ultraviolet spectroradiometers, and UV-Vis spectrometers. Other government-coordinated, instrument-based detection groups collect atmospheric data that are publicly available through the Global Observing Systems Information Center.

Sales of GHG monitors could increase greatly, Thermo Fisher's Nemergut says, if they are added to the government's network of 3,500 national ambient air quality monitoring stations, which are already in place to monitor pollutants such as sulfur dioxide and ozone. Only a few monitoring stations now test for GHGs. Germany, which has 800 stations, and China, which will have 2,000 by year's end, are also potential customers for the monitors.

"Academic customers are the biggest group using our gear," Mark Taylor, gas chromatography products manager for Shimadzu Scientific Instruments, tells C&EN. University and government researchers have been using Shimadzu-based GHG-detecting systems for more than 20 years, and the firm claims to be the market leader in sales of instruments for GHG detection. But at least in the U.S., which is Taylor's market, the industrial GHG detection market has been a nonstarter for the firm.

Shimadzu saw an opportunity to sell its GC instruments to industry soon after EPA issued its GHG reporting rule, which requires facilities that emit at least 25,000 metric tons of greenhouse gases annually to report emissions each year. In January, the firm adapted its GC-2014 analyzer for industrial clients. Shimadzu can install a turnkey system that can be connected directly to an emission stack and programmed to make measurements at timed intervals. "The market for this instrument should be pretty big," Taylor says, "but we're not getting many phone calls."

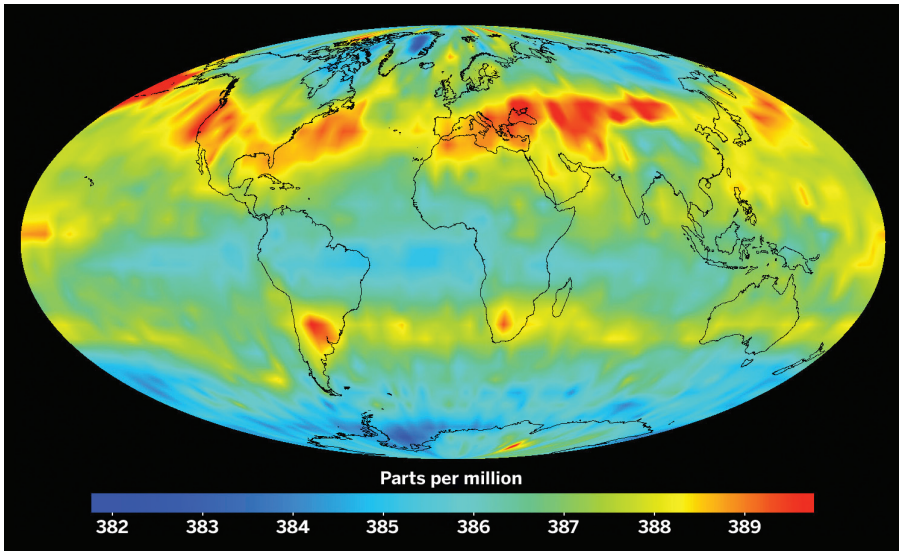
In contrast, industrial orders worldwide for scientific instrument maker Agilent Technologies' 7890A, a gas chromatograph adapted for easy greenhouse gas analysis, have been "strong" since the EPA requirement came out in January, says Cynthia Cai, a business manager for Agilent. The instrument was designed after receiving feedback from European and Asian customers as well, she notes.

Governments are also using the desktop instrument to develop methods to measure and verify industrial site emissions, Cai says. In addition, Agilent is selling a portable micro-GC analyzer, the CP-4900, that was developed by Varian, a company that Agilent recently acquired. Cai says the laptop-sized unit should help customers easily sample emissions from different places on their sites.

Another widely used method for measuring GHG emissions is infrared absorption spectroscopy. The technique has been around since the 1930s, points out Terry McMahon, a principal at consultants PAI Partners. What's new are the relatively inexpensive tunable diode lasers, originally developed for the telecommunications industry, that are now widely used as an infrared source in advanced portable spectrometers.

Their use to measure CO_2 in industrial plant stacks, where they are sometimes part of boiler emissions monitoring systems, has increased in recent years, McMahon notes. The biggest advantage of tunable diode lasers is that they are highly reliable and don't require consumables such as carrier gases and filters, McMahon says.

Companies developing infrared-based GHG measurement instruments tend to be small, entrepreneurial firms. Michael



NASA/JPL-CALTECH

HOT ZONES Map of midtroposphere carbon dioxide concentrations in July 2009 from the Atmospheric Infrared Sounder on NASA's *Aqua* spacecraft.

Woelk, president of Sunnyvale, Calif.-based Picarro, says his 55-person firm is experiencing "robust" growth in sales of its GHG instruments, although he won't disclose sales figures. The company's cavity ring-down technology, licensed from Stanford University, allows the $50,000 instruments to instantaneously detect concentrations of CO_2, methane, and other GHGs.

Its customers are located in 47 countries and include the U.S. EPA, California Air Resources Board, and China Meteorological Administration, Woelk says. Compared with Picarro's portable instrument, a desktop gas chromatograph "is a slow, cumbersome lab instrument," he claims.

In addition, Woelk argues that because Picarro's instruments can give real-time, constant GHG readings, they provide a more accurate picture of emissions than those derived from satellites and monitoring stations, which measure only average concentrations. And if a national carbon tax or trading program ever becomes a reality, the hard data companies get from an instrument such as Picarro's would be more valuable than estimates generated by emissions software programs, he says.

But some companies just don't want accurate GHG measurements because they could expose a firm to unwanted government scrutiny, contends John C. Bosch, a Wake Forest, N.C.-based retired EPA official and part-time consultant to Picarro. "A company's interest is to maximize its sales," he says, and the imprecision of a software-generated GHG estimate gives a firm more operating leeway, he explains.

"IT'S MUCH EASIER for companies to estimate emissions from components and then make a guess," says Bosch, who worked at EPA for 38 years and was manager of ambient monitoring, emissions inventories, and compliance at the National Air Data Branch. Many firms that do so use software that makes GHG emission calculations based on fuel consumption data and other operating parameters. EPA allows firms that don't have stack monitors to estimate emissions.

"Those emission estimates can be inaccurate," Bosch says, because software can't entirely account for fugitive emissions from leaks, pumps, and seals. To responsibly manage emissions, he argues, companies need to constantly survey fence-line readings to limit their emissions' impact on their neighbors. "It's the only way to gather information on GHGs coming from a facility," he adds.

UP THE FLUE Instruments and software calculate unseen greenhouse gas emissions from flue stacks.

Another entrepreneurial instrument maker, Los Gatos Research in Mountainview, Calif., has sold several hundred instruments for government and academic studies of CO_2 and methane emissions, says Manish Gupta, the firm's vice president of R&D.

Los Gatos would also like to tap the industrial market, but uncertainty over carbon regulations in the U.S. has delayed the effort, Gupta says. Several Northeast U.S. states operate the Regional Greenhouse Gas Initiative (C&EN, Feb. 1, page 23), but that cap-and-trade system applies only to large power facilities, many of which already have stack-monitoring equipment in place. And the European Union's carbon-trading scheme relies more on software than on instruments.

Los Gatos has its own cavity ring-down technology, developed by Chief Executive Officer Anthony O'Keefe, and also offers a single-path laser tool, which is a less expensive measuring device that can be installed in smokestacks to monitor GHGs. Los Gatos is working with General Electric, which manufactures power-generating systems, to "deploy our monitors in several facilities," Gupta says.

An additional GHG measurement contender is Warrington, Pa.-based Tiger Optics. The firm's cavity ring-down instruments, based on the work of Princeton University chemistry professor Kevin K. Lehmann, have been used in environmental research. But most of the 800 instruments the firm has sold to date are monitoring industrial gas quality, air in electronics industry clean rooms, and toxic gases in university labs.

"Instrument makers have a lot of missionary work to do" before industrial users widely adopt infrared spectroscopic instruments for GHG monitoring, says Lisa Bergson, Tiger Optics' CEO. "Customers understand the importance of measurement, and in time they'll understand the need to measure emissions too."

ISTOCK

A benefit for industrial firms is that any effort to limit GHG emissions should have a direct impact on energy and fuel consumption, says Alan Rossiter, principal of the energy consulting firm Rossiter & Associates. In some instances, improvements in heat exchanger maintenance, repairs of leaking steam pipes, and tweaks to run boilers at their "sweet spot" could lead to 15 to 20% in fuel savings.

Even without legislation, most large companies are pursuing the twin goals of reducing energy consumption and GHG emissions. ExxonMobil, for instance, said in its 2009 annual report that it had identified projects that can produce savings "equal to 15 to 20% of the energy consumed at our sites." In a May speech, ExxonMobil Senior Vice President Michael J. Dolan made the point that saving energy "is emissions-free."

For Invensys Operations Management, an industrial control systems and software provider, the path to success involves integrating plant measurement systems and controls. But dwelling solely on emissions reduction is a certain path to insolvency, says Peter Martin, a vice president of the firm. "The best way to manage energy and GHG emissions is to turn the plant off," he points out. If a company intends to stay in business, the strategy should be to "maximize the value of the product the plant produces" while controlling energy and material costs.

"No one ever built a plant with the primary objective of avoiding environmental emissions," Martin observes. But "the more you measure, the more you control your business, its profitability, and its productivity. Running a plant efficiently is the best way to reduce GHGs," he says. And if stack sensors help make a plant more efficient, he is all for connecting them to Invensys software and controls.

OTHER SOFTWARE providers say their industrial clients don't necessarily need GHG sensors. A software package that takes readings from a plant's fuel flow, heat value, and mass density monitoring equipment is all that is needed to calculate GHGs, says Rich Hovan, environmental solutions manager for software controls manufacturer Rockwell Software.

The monitoring software, which can cost anywhere from $50,000 to $200,000 depending on the system to be monitored, can compile emissions reports that companies will have to file with EPA. The "continuous emissions monitoring," or CEM package, as Rockwell calls it, can also provide feedback to plant operators so they can optimize boiler operations for both energy savings and GHG reduction.

According to Craig McIntyre, chemical industry manager for industrial controls company Endress+Hauser, software makers such as Rockwell calculate GHGs from the readouts of instruments such as Endress+Hauser's flow meters, pressure monitors, and temperature sensors. Although EPA's reporting requirements are clear, "what goes behind them is not," McIntyre says. If EPA challenges a firm's report, he asks, will it be the manufacturing company, the software provider, or the instrument maker who ends up on the hook?

McIntyre says Endress+Hauser's chemical industry customers, which include Dow Chemical, DuPont, BASF, and Bayer, are taking primary responsibility for the accuracy and traceability of their reports. Many of them, he points out, already voluntarily report GHG emissions under Responsible Care, an industry-wide effort to enhance the safety and transparency of chemical industry operations.

Besides CO_2 emissions, emissions of other GHGs, such as methane, can be predicted by software, and the resulting data can be used to file government reports. Sanjeev Mullick, a product marketing director for process-modeling firm AspenTech, says customers have trouble maintaining instruments, especially under the harsh operating conditions of the oil and gas industry. If clients keep modeling software up-to-date with actual plant operating conditions, they will have an accurate readout of GHG emissions, Mullick maintains.

Regardless of what approach companies use, adapting to GHG regulation will be tough for chemical, food and beverage, and cement plant operators, predicts Eric Baca, environmental sales consultant for software provider Honeywell Process Solutions. Power producers, for instance, already have stack sensors and other measuring instruments installed in their plants to comply with acid rain emissions reporting requirements; others generally do not.

Brendan P. Sheehan, a Honeywell senior marketing manager, sees a role for both software and instruments in GHG monitoring. "We can work with Thermo Fisher and others to incorporate stack monitor readings into our software, Sheehan says. The firm's Cirrus environment information software system can take those readings and generate an emissions report.

Although software may have a role in GHG monitoring, Thermo Fisher's Nemergut argues that instruments are essential to doing the job right. And although Thermo Fisher's customers may only be deploying the company's instruments at the behest of regulators, Nemergut is confident that quality instrumentation will ultimately help those customers operate more efficiently, reduce emissions, and save money. ■