of the powerful Kansai Economic Federation are being "very cooperative".

Japan's electric power companies are particularly keen to develop carbon-dioxide-absorbing technology because they account for about 30 per cent of Japan's total carbon-dioxide emissions. Heavy industry and chemical companies are also hoping to build carbon-dioxide-absorbing plants for their own use and for sale, while trading companies hope to export the plants overseas.

The push to develop environment-friendly technology is not confined to RITE and the marine laboratories. A small but significant effort is under way at the Department of Biotechnology of Tokyo University of Agriculture and Technology led by Tadashi Matsunaga and backed by industry. Researchers there hope to develop a 'biosolar reactor' that will use genetically engineered photosynthetic microorganisms to absorb carbon dioxide and produce useful extracellular products — a project that is closely linked to the work at Shimizu.

Apart from Matsunaga, two other leading academics are spear heading the efforts to develop biological techniques for absorbing carbon dioxide. Shigetoh Miyachi, former director general of the Institute of Applied Microbiology at Tokyo University is executive director for research at the Shimizu and Kamaishi laboratories. And Isao Karube of the Research Center for Advanced Science and Technology (RCAST) at Tokyo University is a leader of RITE's effort.

They all know each other very well, says Matsunaga, and they all sit on committees judging each others proposals, so it is easy for them to coordinate their research to complement rather than compete with each other. One aspect of the collaborations that may seem unusual to Western eyes is the involvement of banks, trading companies and life insurance firms. These firms do not have any say in the research, Miyachi says.

There are, however, several other reasons for such businesses to participate, says Katsuhiko Umehara, senior deputy director of MITI's Agency of Industrial Science and Technology (AIST). Japan's huge trading companies are very diverse and have technology departments that are always on the lookout for the "seeds of new technology and new business". Banks are "very eagerly seeking new customers" and hope to establish business with the new semi-private research organizations. Finally, he says, there is an element of "*matsuri no kifu*" — a Japanese phrase that translates roughly as a "donation to the village festival", implying that the companies contribute for no reason other than the wellbeing of the community.

It was, of course, just this type of long-term thinking that helped Japanese industry to dominate the rest of the world in selling such things as video cameras and home stereos. The Japanese are hoping to repeat their success in the coming market for technology to keep the world green.

David Swinbanks.

Algae to the rescue

Koganei & Shimizu

Tadashi Matsunaga and Shigetoh Miyachi, two of Japan's leading microbiologists, believe that tiny, genetically engineered photosynthetic microorganisms may help to solve worries about global warming by mopping up carbon dioxide emitted from power stations and industrial plants. And Japanese industry and MITI are prepared to back their ideas.

Matsunaga, who heads the department of biotechnology at Tokyo University of Agriculture and Technology in Koganei in the outskirts of Tokyo has built a

Looking for algae at Palau.

2-litre prototype 'biosolar reactor' that can absorb all the carbon dioxide out of ordinary air bubbled through the reactor at 300 millilitres per minute. The reactor contains a genetically engineered marine cynanobacterium, *Synechococcus sp.*, and is filled with a stack of 600 light-diffusing optical fibre cables that ensure even lighting and optimum growth of the bacterium throughout the vessel.

The optical fibre cables, which, unlike conventional optical fibres, emit light of constant intensity laterally as well as along their length, were developed by a two-man Japanese venture company Science and Technology International and are a vital component of the bioreactor. Previous attempts by Matsunaga's team to absorb significant amounts of carbon dioxide were confounded by the fact that green-coloured photosynthetic microorganisms rapidly attenuate incident light and only those within a few millimetres of the light source can grow efficiently. The stack of closely packed optical fibres overcomes this problem by providing a constant lateral glow. In an industrial-scale biosolar reactor sunlight would be fed into the fibres (hence the name biosolar).

Matsunaga's reactor, however, is still a long way from providing a practical means of absorbing carbon-dioxide emissions from power plants and industry because the levels of carbon dioxide in such emissions are much higher than the 0.03 per cent in air. And high levels of carbon dioxide usually inhibit growth of photosynthetic microorganisms.

But researchers working under Miyachi, who heads MIT's marine biotechnology laboratories in Shimizu and Kamaishi, may have found a solution. They recently isolated a strain of marine green algae off the coast of Kamaishi that grows happily at concentrations of up to 20 per cent carbon dioxide. By isolating the genes responsible for carbon dioxide tolerance, they hope to genetically engineer strains of microorganisms that can efficiently assimilate carbon dioxide at high concentrations.

Even so, it would require an enormous biosolar reactor to cope with the output of a power plant. Matsunaga says a typical megawatt-class power plant emits about 200 tons of carbon dioxide per hour. And if the biosolar reactor absorbed only a few per cent of this it would produce several tons of algal sludge per hour.

Matsunaga and Miyachi differ on how to deal with the sludge. Miyachi hopes to create strains of calcareous algae that can mop up the carbon dioxide and convert it into calcium carbonate that can be dumped at sea. His laboratories have been searching for suitable strains of calcareous algae in coral reefs in Palau and the Great Barrier reef off Australia.

Matsunaga, on the other hand, is trying to create strains of photosynthetic microorganisms that produce useful extracellular products that are released into the green brew of the reactor. For example, the *Synechococcus* in Matsunaga's prototype reactor has been genetically engineered to produce the amino acid glutamate. And his team have other strains that produce antibiotics and plant growth hormones.

A remarkable feature of the research by the two groups is the enthusiastic backing it is getting from industry. Matsunaga's research is supported by six companies, including a cement manufacturer, Onoda Cement, and Pentel, a maker of ball-point pens, through a new cooperative research centre at Matsunaga's university that was established by the Ministry of Education, Science and Culture last April to encourage collaboration with industry.

The education ministry and industry are providing him with ¥30 million each in fiscal year 1991 to build a 30-litre biosolar reactor and other facilities. And Matsunaga hopes to bring the total up to ¥100 million ($750,000) a year with other donations from industry. He has a team of 30–40 researchers, about a quarter of whom come from the supporting companies.

Similarly, Miyachi's laboratories are staffed almost entirely with people from industry and the laboratories receive substantial support from MITI and private companies. Most of the researchers are beginners in biotechnology and marine science but Miyachi boasts that these 'brave laymen' isolated the strain of marine algae tolerant to carbon dioxide that might one day help solve the global warming problem. **D.S.**