Session 2: Low Environmental Impact Transportation Systems

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E. Yamaguchi (Chair)
The lack of an antagonist in the carbon dioxide (CO_2) reduction debate prompts a rather trivial level of discussion. I'd like to make this workshop a provocative occasion that brings in some controversy. With that in mind, I have selected the three themes of liquid nitrogen engines, electric cars, and ITS technology.

Firstly, the story of how limited water resources and slow progress in producing a viable steam engine saw Germany instead struggle through to create the internal combustion engine is well-known. It's strange that this mid-19th century technology should remain a de facto standard some 150 years later. As my first provocation, therefore, I'd like to go back to thermodynamics basics and revisit the Otto cycle. I'm sure you all know that, according to thermodynamics, the ideal heat engine for converting thermal energy to dynamic energy is the Carnot cycle. In that case, it would seem that instead of the Otto cycle, which uses a gasoline explosion and produces CO_2 and polluting gases, we need to give serious thought to the Carnot cycle, which exploits transitions between physical phases. First, I'd like to ask Dr. Hayashi from Aoyama Gakuin University to explain to us why auto firms need to address this issue.

Time for Liquid Nitrogen Car and Compressed Air Vehicle

Koichi Hayashi
We have a tendency to focus on the short-term issue of cleaning up engine exhaust, but I think there is certainly something to gain in pursuing Dr. Yamaguchi's suggestion here and taking a long-term perspective in considering a completely different engine, namely a method that does not use the internal combustion engine, which I will talk about today.

We know that it will be a while yet before fuel cells are viable, and instead we could see the dramatic emergence of a new paradigm based on the liquid nitrogen car (LNC) and the compressed air vehicle (CAV).

The LNC was first proposed by Professor Abraham Hertzberg from the University of Washington in Seattle. Luxemburg-based firm MDI Enterprises S.A. has had a CAV out on the market for some years now, but because high-pressure tanks remain heavily regulated in Japan, these cars can't yet be operated on Japanese roads. In fact, when liquid nitrogen that has been cooled to minus 196 degrees Centigrade is released into the air, this alone increases its volume 1,000-fold. My laboratory created such an LNC system in 1998. Our LNC has a liquid nitrogen tank, and the liquid nitrogen is heated using a heat exchanger. The air control system entails depressing pedals the same way as in a car to adjust the valves, etc., allowing the vehicle's speed to be increased or decreased.

In the case of liquid nitrogen, the key technology is minimizing energy loss. When we began research nine years ago, the main players were my university, the University of Washington, and the University of North Texas, and we were all getting roughly the same mileage. The speed generated through nitrogen pressure was around one or half a percent of our goal. The maximum speed on our first try was around 25 km/h, topping out at 40 km/h at full throttle. By comparison with light motor vehicles (cars with engines up to 660 cc), we are clearly achieving the same torque but the power is entirely different, and I think that sooner or later a vehicle will emerge that meets requirements.

When we borrowed a track from an auto company to try the car out, moving with all the windows open made for an extremely cold experience, partly because it was winter, and partly because of the vaporized gas from the liquid nitrogen. One reason that the windows had to be opened was safety, as people can suffocate on vaporized nitrogen. In addition, we needed to draw in the outside warmth.

Turning to CAVs, I developed an interest in these back when I was building the LNC. Compressed-air vehicles emit the cleanest air. In that sense, they are the ultimate car. However, because liquid nitrogen and compressed air both constitute secondary energy storage, some form of energy needs to be used to create them. At this point, high-pressure air is sitting at around 300–400 bar, but there are plans to use tanks with high-pressure nitrogen of around 700–800 bar, and if these are realized, I think that high-pressure air could be used in tanks in place of nitrogen.

CAVs can use either turbine or piston systems. We started out with a turbine system. MDI in Luxembourg is currently selling small CAVs, but only two or three weeks ago, an Indian firm called Tata Motors too announced that it will sell a CAV for around US$3,000. The key point of this model is that because it is a gasoline hybrid, it uses a normal piston-driven car engine. CAVs generally have 600 cc engines producing up to 33 hp, so they really are comparable with a light motor vehicle. A lot of infrastructure would have to be put in place before these cars could be used on the roads, including the deregulation of high-pressure tanks and the construction of air stations, but in our case, I think we could get by using electronics stations and on-board compressors. What I'm aiming for is a hybrid electric-compressed air vehicle that uses no gasoline at all.

The energy efficiency of our LNC is around 37. MDI's is about the same, but their overall efficiency is around 70 percent in theory, so one key issue will be how far performance can be improved in this regard. In short, CAVs are achieving greater efficiency than LNCs.

Questions

H. Tsukamoto (Quallion)
With a compressed air system, regeneration should allow energy to be recovered when the car goes down a hill or decelerates.

K. Hayashi (Aoyama Gakuin)
That's right. We are aiming to control all those elements by computer. If we can do that, we should be able to create a fully-fledged regeneration system.

H. Tsukamoto (Quallion)
It sounds like an outstanding system in terms of handling power fluctuations, but isn't the energy density much lower compared to batteries?

K. Hayashi
Of course. We will need to look at how to increase the energy density, but I don't think it's an impossible task.

E. Yamaguchi
Next, I'd like to ask two of our panelists to talk about electric cars. The electric car is another paradigm that could replace the engine. Let's assume that secondary batteries or fuel cells are used as devices for supplying energy to the motor. However, it's our view that fuel cells will not be a viable option for a while yet. Looking ahead 10 years, therefore, it was suggested that we should push hard instead to get lithium-ion batteries into a system. But while lithium-ion batteries are environment-friendly, they currently only allow for a single-charge cruising range of around 400 km, or, on a daily use basis, a maximum of around 200 km. In the case of fuel cells, Nafion polymer membrane is sickly and has problems that no one seems able to fix. Can the electric car paradigm truly be realized? I'd like to ask Dr. Tsukamoto to address this question.

Energy, Environment and Battery

Hisashi Tsukamoto
The United States currently consumes a total of 100 quads of energy per annum. Petroleum accounts for around 40 percent of this, with around 60 percent, or 24 quads, of petroleum imported from offshore.

In terms of consumption, of that 40 quads of petroleum, light-duty vehicles, freight/other and aircraft account for 28 quads. This means that 70 percent of petroleum, or 28 percent of total energy consumption, is being consumed for transportation. Improving energy efficiency in transportation will consequently be vital in addressing the energy problem. At the same time, 55 percent of energy is currently being lost, turning into heat and vanishing. Major losses occur in the process of conversion into electrical energy and the process of moving electrical energy. To reduce these losses, it will be important not only to boost the efficiency of the various processes, but also to work on electrical energy storage technologies.

The only way to store electrical energy is in batteries, which makes battery technologies absolutely critical. Means of boosting transportation technology efficiency include hybrid electric vehicles (HEVs) and plug-in hybrid electric vehicles (PHEVs), but again, battery technologies will be crucial in realizing these. Particularly when it comes to energy density, lithium-ion (Li-ion) battery technologies take center-stage.

There are three issues with Li-ion batteries: (1) safety; (2) performance (particularly longevity); and (3) cost. Various chemical improvements have been suggested to ensure safety. Quallion uses heat absorption material (HAM) as a simple and practical method. Laptop computer batteries burn because the batteries touch. Quallion leaves a bare 1 mm gap between batteries, in which we insert heat-transferring HAM. Our proposal is a large-scale battery system combining very safe 0.5 kWh, 48 V modules that use HAM. In this system, a number of modules are linked to create one large system. There is a central control unit that orchestrates all the modules, and this is designed with 500 V resistance. We believe that this Li-ion module system will enable the safety issue to be resolved.

Our medical and aerospace Li-ion batteries are generally designed with a target of around 60,000 charge/discharge cycles. Actual data suggests that they run at 20,000-30,000 cycles, but given that our tiny 170 mAh medical battery, which features the same design and the same materials as our large 72 Ah aerospace battery, also demonstrates exactly the same cycle performance, we should be looking at a little over 70 percent capacity retention over 60,000 cycles. Given these figures, I don't think longevity is a major issue either, while batteries also appear to provide adequate output. Perhaps the only technical issue remaining in regard to performance is charge acceptance.

The real problem is cost. Li-ion batteries will not be able to beat lead batteries on cost in a million years. The cost issue will therefore not be resolved through battery technology, but rather by coming up with a new business model.

In the United States, they have been researching the vehicle-to-grid (V2G) concept for almost 10 years now. These systems use the car as a distributed energy storage device, with plug-in hybrids and other cars drawing power sitting idle in power grids during the night. During the day, the car is driven to work, where it is again plugged into a socket. In the case of California, thermal electric power stations are operated just for two or three hours a day in the summer to meet afternoon peak power demand, but a V2G system would see the grid instead drawing power from many cars linked to the grid using the energy they have stored during the night. In addition, even slight phase shifts during peak times can cause major energy losses. Linking a large number of batteries to the grid would mean fewer phase shifts and, accordingly, greater energy efficiency. Some power companies have apparently offered to pay US$3,500 per annum per car to anyone prepared to join the scheme, and firms like Google are working hard to develop and implement business models. This would certainly be one way of addressing the cost issue.

However, what I regard as the truly key issues relate to patents and business. Very few Li-ion battery patents have been taken out in the U.S. and Europe, and given the difference too in terms of knowhow and manufacturing technology, Japan is by far and away the world leader in the battery field. In the early 1990s, Japan was first in the world to develop and manufacture the Li-ion battery, carving out an overwhelming monopoly by the mid-1990s. However, as of around 1999, the Samsung Group developed lithium-ion battery operations in the space of two or three years, becoming the world's third largest battery manufacturer in the blink of an eye. Japan's patents were completely unable to prevent this. Developing innovative technology but failing to draw sufficient profit from it during the initial phase can be ascribed to nothing but a lack of business savvy on the part of Japanese business leaders.

Many iPod components, as it happens, are Japanese. We excel at making devices, but we were unable to produce a system like iTunes. This time too, even if we create an innovative PHEV battery and outstanding electric cars, the real profits will probably go to Google and the electricity supply system it is creating. If we continue to win on tactics while continuing to lose on strategy, sooner or later fatigue will set in and our efforts will go to waste.

Japanese patents are not a reliable means of preventing technology outflow. Battery manufacturers need to create a system for producing their materials in-house to the greatest possible extent, blackboxing materials and technology from outside eyes.

In terms of new business models, because Li-ion batteries are expensive, one possibility could be for manufacturers to set up lease operations. For example, batteries could be leased out to car buyers for the initial four years only at US$2,000 per month. The battery would be returned after four years, and then leased out again for fork lifts and other applications that don't require pulse power, or applications with a 10-20 hour discharge period. After a further eight years, or 10-12 years into the battery's life, it could be leased once more for low-discharge applications in the home or for large-scale energy storage systems. Approaches such as these should open the way for new business models.

Questions

T. Ikoma (Center for Research and Development Strategy, Japan Science and Technology Agency [JST/CRDS])
Is the military driving U.S. battery technology?

H. Tsukamoto
The military isn't the biggest client for the battery business. Because batteries are a volume business, there's no point catering for clients like the military, which only buys small quantities. Those companies that are developing technology for the military are not going to become technology leaders in the battery industry.

I. Yamamoto (Mitsubishi Chemical)
There was mention earlier of a vertical business model. Why can't a vertical business model be developed for lithium-ion batteries?

H. Tsukamoto
In the case of lead and nickel-cadmium batteries, active material and electrolytes are generally produced in-house. When nickel-hydrogen batteries were commercialized ahead of Li-ion batteries, manufacturers started buying in active material from outside the company. I think that's where the tendency to buy in active material arose from. Then in the case of Li-ion battery development, manufacturers had to create electrolytes, separators, anodes, cathodes, and binders in a short period of time, so they didn't have the capacity to do everything in-house. However, because of this, element technologies have flowed out despite our patents for batteries, spreading quickly to Korea, China, and all over the world.

E. Yamaguchi
Now let's hear about the materials side of electric cars. I think that realizing a low environmental impact transportation system will require radical innovation in so-called materials technology in a broad range of areas ranging from batteries to weight reduction, sensors, and inverters, but these technological innovations don't tend to be visible to the public. If we take the case of inverters, we've lived in a silicon paradigm for years now, but silicon has extremely low pressure resistance. Silicon carbide (SiC) and gallium nitride (GaN) have been used for the last 10 years as silicon replacements, but despite being Japanese innovations, all the firms that have made business out of them have been American. What on earth is Japan doing?

Then, while cars generally weigh 15 to 20 times more than a human body, this ratio really needs to be reduced to 10 times at the most. However, the breakthrough technology necessary to create such lightweight cars has yet to emerge. Could we please hear from Mr. Yamamoto from Mitsubishi Chemical, who is conducting perhaps the most comprehensive research in this area.

The Realization of an Environmentally Sustainable Transportation System

Iwao Yamamoto

In the case of our current nickel-hydrogen batteries, we have achieved an energy density of 50 Wh/kg with nickel hydride (Ni-H) for hybrid car use, but we're aiming to improve this slightly by, for example, using lithium batteries and moving from hybrids to plug-ins. However, where horsepower is central to the system, you can't use a lot of energy density as a whole, so the cruising range remains limited. With electric cars, we want to focus primarily on cruising range, so that's where we're working to develop lithium-ion batteries. With the all-electric car, we're aiming for a vehicle that will run 400–500 km on a single charge, as Dr. Yamaguchi suggested earlier, and that will require particular materials. At the same time, costs will also need to be reduced to 10 percent of the current level.

However, the top cruising range with lithium-ion batteries is regarded as being around 250 km, and there has been discussion within Mitsubishi Chemical as to what materials could be used to produce a battery that will last for 400–500 km. We did some calculations on how many kilometers an electric car might run if it was loaded with a 130 kg battery with an energy efficiency of around 10 km per kWh, and we discovered that where a car with a nickel-hydride battery will only run just over 10 km, a car carrying a battery with an output of 100–150 Wh/kg will run roughly 250 km on a single charge. We based these calculations on a lithium-ion battery designed for car use, but if the vehicle were to be powered by an industrial-use battery with an improved energy density, our estimates suggest that an output of around 200 Wh/kg should be possible. Even so, however, the limit of our current technology lies at a cruising range of more than 250 km but less than 300 km. Once the safety aspect has been covered, I doubt the maximum distance would be more than 300 km. One proposal, then, is that what we have to do is come up with the innovations to stretch that distance a bit further to 500 km.

Put simply, the structure of a lithium-ion battery is based on one lithium ion inserted per six atoms of graphite carbon, with efforts currently focused on the number that can be squeezed into the same volume. The key is to choose something lighter and more compact to replace the six carbon atoms enclosing the lithium. Other solutions that seem feasible from the perspective of a materials manufacturer are to raise energy density by replacing the lithium with a hydride ion, which has a lower ion density, or to bring in something that carries two ions. One of our current technology development projects uses silicon, with 22 lithium atoms inserted per five silicon atoms. This is expected to increase the energy density by six times.

However, targeting the anode alone has its limits, and we really need to change both the anode and the cathode as a set. The main cathode materials are currently manganese, nickel, and cobalt oxides, which can accommodate one lithium ion per atom. Looking at the materials for a breakthrough in this area, for example, three lithium ions could be inserted per two vanadium atoms. If these cathode materials were matched with the right anodes, the energy density would improve by around 1.4 times. Then, if we continue this line of thought we arrive at the idea of using oxygen, a gas, as the cathode material. Combining lithium metal and oxygen has the potential to provide the ultimate secondary battery, so we're currently looking at putting together a battery along those lines.

In addition, because power density is power per unit weight, a key point is to keep the battery as light as possible. For example, one approach could be to change the current collecting plate and the case. For instance, in the case of a dome-shaped plate, we could lighten the plate by using a structure comprising a thin sheet of carbon fiber reinforced plastic (CFRP) coated with copper. Or we could use a resin case rather than a metal one. The plan is to develop a battery by substituting composites where changes are necessary.

Because moving from metal to CFRP reduces the weight to around 25 percent, we examined what would happen in that case. Because we can assume a current energy density in lithium ion batteries of up to around 150, we can make changes—using silicon or divalent vanadium for the cathode, for example—to produce essentially the same battery designed to different weights. Moreover, because the battery is extremely compact, we can expect the electrolyte and the separator to drop simultaneously. Building in all these factors, we should be able to boost output by around 1.8 times, and if we were to achieve a breakthrough in this direction, I think we would have a significant innovation on our hands.

In the second-floor showroom at Mitsubishi Chemical's headquarters in Tamachi, Tokyo, we have a car on display that is made as completely as possible of resin. It is a relatively standard-sized car—4.2 meters long, 1.8 meters wide, and 1.5 meters high—and would normally weigh about 1.2 tons. However, by using CFRP for the frame and the chassis and polypropylene-based resin for the body, and replacing glass with hard-coated polycarbonate, we've achieved a substantial reduction of that weight to 890 kg. As a result, efficiency has been boosted by perhaps 1.3-1.4 times, approaching that 500 km cruising range. In other words, where battery technology is used to achieve an energy density of around 270-280 and the weight of the car is also reduced, a 500 km cruising range becomes a real possibility from a materials approach.

Finally, I'd like to turn to gallium nitride. Mitsubishi Chemical is currently developing a market for gallium nitride as a crystal material in its inorganic materials business. More specifically, we are developing a LED for battery use which, compared with incandescent light bulbs, requires much less energy and is about 1.5 times more efficient. The current battle is to reduce the flaws in gallium nitride crystals to the greatest extent possible to create a clean crystal, but we are also working on the cost front. We have already achieved a level of technology that will allow gallium nitride to be used for illumination, Bluray disc system lasers, and communications, but impurities will have to be reduced by single or even double figures before the crystals can be used in inverters.

Where gallium nitride crystals are used in cars, inverter efficiency is expected to improve by 3 percent and fuel efficiency by around 10 percent. Inverter volume will be reduced to an eighth, opening up a lot of space. In addition, because the inverter will also become extremely heat-resistant, it won't require cooling, thus saving on energy. Given technology development in these various related areas, I think there are definite possibilities for the electric vehicle.

However, no matter how hard we work on electric vehicles, if we don't look at aspects like recharging systems, mechanisms for recharging even after travelling 500 km, social infrastructure, and energy sources for the electricity used in recharging, we won't see a reduction in CO2. Mitsubishi Chemical is therefore currently looking to launch photovoltaic cell technology, which, combined with our electric vehicle-related innovations, we're hoping might generate various new forms of social infrastructure.

Questions

Ihara (Tokyo Institute of Technology)
At the Research Center for Carbon Recycling and Energy, we are looking at the electric car primarily from the perspective of fuel cells, and we're also doing a little research on photovoltaic cells. You were saying that we still need more capacity and greater energy density, whereas Dr. Tsukamoto suggested that technical issues had mostly been overcome. Is it that the two of you have conflicting ideas on whether the current level of technology is adequate at the scale necessary to reduce CO2, or does the situation simply differ according to the scale?

I. Yamamoto
What we're aiming to do is change contemporary culture in its entirety. As far as technology goes, there probably aren't that many people who drive more than 200 km a day, so a car that could handle 100 km would be quite adequate.

H. Tsukamoto
The battery system that my company is proposing is not the ideal battery for transportation. At the moment, there are no investors because there is no market, but if we can market what we already have and it becomes apparent that the market is growing, I think that everyone will invest. That's what we're aiming for. There's no conflict at all in what Mr. Yamamoto and I are saying.

Tatsumi (National Institute of Advanced Industrial Science and Technology [AIST])
There are perhaps two or three major hurdles in developing a car that applies battery technology. For example, Dr. Tsukamoto presented a vision of how to take development forward with a cost focus, while Mr. Yamamoto looked at performance aspects.

H. Tsukamoto
It won't be until cars are actually running on batteries and serious problems arise—accidents, for example, or cars bursting into flames or stopping in the middle of a motorway, or service problems—that we'll understand what is actually ideal. That's why I think the current priority is just to get these cars moving.

E. Yamaguchi
I'd like to change the topic and this time discuss telecommunications infrastructure. In my personal view, information and communication technology (ICT) has not progressed at all since back in 1989 when the European Organization for Nuclear Research's Tim Berners-Lee invented HTML and caused paradigm destruction with the Web. There have been paradigm-destroying innovations in the fields of solid state physics and quantum electronics over the last 15 years, but most ICT people in Japan don't seem to know that and are pursuing trivial research without even trying to create a new concept. Could I call upon Dr. Morikawa to refute this provocation?

The Sensory Car—A Ubiquitous Perspective

Hiroyuki Morikawa
"Ubiquitous" is a term generally used to mean "whenever, wherever, whoever." We see the ubiquitous interaction with the physical and virtual environment as something very different from today's Internet. In the case of the Internet, all services have been provided on a closed basis in a virtual environment, but if sensors and actuators are disseminated in the real world, various new uses should emerge.

We envisage four steps on the path from "mobile" to "ubiquitous." The first step is to shift all mobile phones to IP-based networks. We've reached the stage where this is quite feasible, and at some stage mobile phones too will doubtless be switched to a flat-rate system. The second step will be seamless movement among multiple forms of wireless access (2G mobile phones, 3G mobile phones, wireless LAN, WiMAX, PHS, DSRC, etc.). The third step will be for various terminals to exist ubiquitously around us, with all these devices communicating with each other. The final step will be for sensors and actuators to be embedded around those various terminals, creating a truly ubiquitous environment.

To pick up on this final step, many mobile phones already have sensors embedded in them. Our laboratory is conducting an experiment whereby students are given mobile phone acceleration sensors to carry at all times so that we can garner information on students' movements. Just through the use of the acceleration sensors, we can generally tell whether the person is standing, walking, or just hanging around. We call it the Privacy Zero Project, or P0P.

Some years ago, Tim O'Reilly defined Web 2.0 as comprising free organization of information by users (Flickr, Hatena), rich user experiences (Gmail, Google Maps), user contributions (Amazon), the "Long Tail" (Google, AdSense), user participation (blogs, SNS), reliable content, and a decentralized network. I think that Web 2.0 has two key elements. The first is mechanisms like YouTube that collect content. The winners here are those who manage to create a mechanism that allows easy collection of user-created content. The second are mechanisms to collect and use personal information, and our P0P project addresses this aspect. Take, for example, the fictitious company called Googlezon, which was built on a combination of Google and Amazon. Such a firm would have certainly the potential to become a Big Brother. Google determines users' tastes (future preferences) from keywords in their searches, while Amazon collects purchase histories, and together they would be able to piece complete histories. Googlezon would therefore be gathering all this individual information from the past through to the future. Most of my students use Gmail, but Gmail allows Google to gather information on each individual's e-mail content. When you push the "I agree" button, you are consenting to Google gathering information. Another firm, a U.S. start-up called IMMI, uses mobile phones to conduct audience rating surveys. They give out free mobile phones in exchange for permission from the new owner to have the phone mike switch on for five seconds out of every 30 so that the firm's server can collect the peripheral sounds as a type of audience rating survey. Applying the same perspective to cars, we would like to see the emergence of "sensory cars." For us, the car provides a wonderful field in that it has few power source constraints, and appears to have a lot of space in which to incorporate new elements.

From that perspective, we have been placing sensors all around Akihabara, collecting "privacy zero" data, information on building movement during earthquakes, and other types of information. At this stage, we don't know what can be done with the information that has been collected, but as firms like Google are collecting information, it seems that the important thing is to start with this collection process. For example, when sensors are put out there to gather real-world information, information from the sensors that has some meaning can be screened by a context extraction platform and distributed across a network. We could see information gathered from various types of databases being matched for various purposes—for example, the identification of threats, community support, and dealing with metabolic syndrome.

In addition, because applications related to safety and peace of mind will become increasingly important, I'd like to see these applications developed with the car as a primary focus. We also need to think about the relationship between ICT and CO2 reductions. One approach would be to cut the power consumption of ICT devices. There's no need for home broadband routers to be on 24 hours a day. The development of new networks also needs to incorporate this perspective. Another approach would look at the system as a whole. Possibilities could include green commerce that allows trade-offs of CO2 emission volume at per-bit prices, or green grids that locate data centers in areas with rich natural resources. Then there are transportation systems, e-health, and e-learning, etc.

In 1853 when the telegraph was invented, one newspaper article made this declaration. "We call the electric telegraph the most perfect invention of modern times … as anything more perfect than this is scarcely conceivable, and we really begin to wonder what will be left for the next generation, upon which to expend the restless energies of the human mind." In fact, 20 years later the telephone was invented, and 50 years later we had mastered flight. Looking ahead, of the "take, connect, store, use" elements, for "use" in particular, my goal is to come up with something truly groundbreaking and incorporate it into the various relevant technologies.

Luncheon discussion

E. Yamaguchi
As we haven't really talked about fuel cells, I'd like to start our luncheon discussion with comments from key figures in the world of fuel cells. Polymer membrane and catalyst technology development in particular has been slow, while the prospect of ethanol reforming to generate hydrogen seems to be fading, with a return instead being made to high-pressure hydrogen. As a technology, therefore, fuel cells seem to be rather lacking. Is a breakthrough likely? I'd like to hear the views of our experts.

H. Tsukamoto
I'm interested in high-temperature ceramic fuel cells as on-board chargers. In other words, these wouldn't power the car directly; rather, they'd be small fuel cells that constantly recharge the main battery whether the car was moving or still.

In terms of fuel cell chemistry, I have always thought that the potassium hydroxide electrolyte, which I developed more than 20 years ago, could still be used today.

I. Yamamoto
There seem to be large gaps between theory and practice when it comes to, for example, technological breakthroughs on fuel cells, the amount of time before the necessary social infrastructure is in place, and the actual likelihood of the materials and various roles for electric cars. My impression is that fuel cells will require quite a number of technological breakthroughs.

Ihara
I've actually been working for a long time now not on polymer electrolyte fuel cells (PEFCs) but rather on solid oxide fuel cells (SOFCs), which have very polymer-like properties. A key example is a SOFC that creates electrical properties within zirconium, which has the merit of producing no poisonous carbon monoxide. PEFCs present two major problems: carbon monoxide poisoning and, because hydrogen has to be used as fuel, the fuel efficiency of hydrogen. However, because high-temperature PE-type fuel cells operate at high temperature, carbon monoxide poisoning is not an issue, and hydrocarbons only need some direct steam reforming. Therefore, in terms of future potential, these fuel cells could be realized slightly after PEFCs to become the final shape of fuel cells for electric cars.

Horiba (Hitachi Vehicle Energy, Ltd.)
I'm currently in charge of our lithium-ion battery project, but in the 30-plus years that I've been with the company, I've been

involved in research and development (R&D) on virtually all battery types. Comparing all of these, I used to think that fuel cells performed poorly in terms of energy density, or power density. However, it looks as though the new PEFCs will improve that power density.

However, what we engineers currently face is the rather fatal flaw of the use of platinum, which represents a major obstacle in terms of achieving a popular electric car. Glancing at a newspaper today, I noticed that Daihatsu is apparently pressing forward with the development of a hydrazine-air fuel cell. If they succeed, they will have an aqueous fuel like those used in alkaline fuel cells. This would remove the problem of high-pressure hydrogen cylinder filling. They would also be able to avoid using platinum. One problem would be contamination by air, although this would probably be surmountable if a film and other technologies were developed to block CO2 rather than oxygen.

Nevertheless, given that such delicate balances between liquids and gases, and between liquid and gas layers, don't last indefinitely, I lean toward the lithium and oxygen combination that Mr. Yamamoto described as the ultimate battery. However, in a sense this combination presents similar challenges as fuel cells that use air, and the question is whether we can expect future breakthroughs in the relevant materials. We might end up with so-called "air batteries", or lithium-air batteries, or we might end up with fuel cells that use air. If we could realize these technologies, I think we would see batteries with dramatically improved performance and fuel efficiency.

Y. Nishiguchi (Kyocera Corporation)
Kyocera is developing a SOFC. We have been pursuing R&D on ceramics for the last 15 or 16 years, and currently have a few dozen home models installed in field test participants' homes where we're conducting monitoring tests.

In one sense, SOFCs are very simple. They currently combust at around 720–730 degrees, but this will certainly be brought down to around the 600-degree mark. This should also allow the cells to be used with propane gas, city gas, and heavy oil. And because there is no need to create extra hydrogen, the infrastructure burden too will be much lighter, while there is also the possibility of a car application. I hear that efficiency still needs to be improved slightly before the weight issue can be resolved, but I think the possibilities are very real.

H. Tsukamoto
The issues with fuel cells are that the electrodes are expensive, we haven't been able to raise the power density, and we don't yet know how to get our hydrogen fuel to the tank. If we were to use on-board chargers the cars would be electric vehicles (EVs) and not electric and hybrid vehicles (EHVs), but as a user I don't want to be charging my car by plugging into a socket. The aim should be that when the charger is hooked up to the battery, the battery charges itself automatically as necessary. Where chargers are used, the issue of raising power density disappears.

Turning to the question of getting hydrogen to the tank, if you look at U.S. maps, you'll find not only oil but also ammonia pipelines. Because ammonia is everywhere, it can be plucked to make hydrogen. As this is something that could be easily achieved with a small device, what about charging with ammonia? And ammonia also has very low toxicity. I wonder whether we couldn't use an ammonia-alkaline solution for on-board chargers.

Hasegawa (AIST)
The AIST only researches PEFCs, but I'd prefer the technology to be described as immature rather than sickly. The relationship between fuel cells and auto companies has been both a blessing and a curse. What has been a blessing is that at recent symposia, auto system specialists have been calling for the creation of materials suited to systems. Because materials of the level they require have yet to be developed, various means have been invented to compensate for shortfalls in existing materials. In particular, as electronic devices, modern auto systems have extremely good control authority, and full use is being made of that control. However, to bring costs down, auto systems manufacturers need to simplify their systems a little further. In turn, they are demanding more from materials. Part of this call probably arises from auto companies' view of materials makers as alchemists, who, if pushed constantly on a number of fronts, will succeed in suddenly opening a magic box and pulling out something interesting.

The curse has been that auto companies are extremely good at making fuel cell cars. As a result, they are producing very polished vehicles while fuel cell manufacturing is still in its infancy. I think that's what has caused the sense of a "reality gap" in the market at the moment. However, materials manufacturers are making steady progress with materials development. It may just be that materials development is moving on a longer time axis than that assumed by car companies and society. But it certainly isn't appropriate to describe it as sickly.

I think the biggest problems are—and this includes the issue of car disposal—how to extract hydrogen while minimizing CO2 emissions, and how to dispose of our current cars and make the shift to fuel cell cars without producing CO2. Because the only thing that auto firms can't do is to extract energy, I think that link is crucial.

E. Yamaguchi
Moving on from fuel cells, I'd like to ask your views on Dr. Hayashi's liquid nitrogen car.

Ookijima (Toyota Motor Corporation)
We are treating both hydrogen and nickel as secondary energy. Ultimately, once the energy has been supplied, the conversion process is something that the car handles, so the real question is how to supply the liquid nitrogen. Unless you go back as far as considering how much energy to use at that point and what to use to provide that energy—fossil fuels or whatever—you haven't actually managed to break away from petroleum or solve the CO2 problem.

If electricity, nitrogen, and ammonia are renewable energy options, we can certainly make a device that takes these and converts them to energy. And if liquid nitrogen can be used extremely cheaply and without requiring much energy, we will obviously have to pursue that route. For example, we can say that EHVs are definitely better than ordinary gasoline-driven cars in terms of energy use and CO2 emissions. However, while EHVs are fine for France and other countries that are powered primarily by nuclear power, power generation in China, on the other hand, is primarily coal-fired, which could mean that EHVs ultimately produce more CO2 than gasoline hybrid cars. We do have to think about energy sources.

Tatsumi
From what Dr. Hayashi was saying earlier, I gather that the idea is to store and then use the heat gained from vaporizing liquid nitrogen. As heat gained in this way will be only around one percent of the heat produced by gasoline, you're going to end up with gasoline as primary energy and whatever else, be it electricity, hydrogen, or liquid nitrogen, as secondary energy. And gasoline is far more superior in terms of both ease of storage and volumetric efficiency.

From Dr. Hayashi's presentation, we can also expect a well-to-tank efficiency—the efficiency of getting the liquid nitrogen to the car—of 37 percent. The current well-to-tank efficiency of gasoline is perhaps more than 90 percent. The selection of energy source therefore has two meanings. Firstly, there is the issue of user convenience, and secondly, there is the issue of whether we achieve an overall CO2 increase or reduction.

If I may make another point, because the primary source of energy for electricity can be selected from a rather extensive portfolio, we might be able to reduce CO2 emissions. However, fuel cell usage is such that when the electrical energy is transferred, the energy could be quite "thin." For example, if by contrast you calculate the thermal value of gasoline, you're probably looking at a charge of some thousands of kilowatts of energy. Are we looking at something that the average person will be able to use straight away?

When it comes to the use of the heat of vaporization to which Dr. Hayashi referred, the issues here are energy density and, no matter how the primary energy is brought in, efficiency. I also gathered that an additional issue to be dealt with is the technical problem of how to store the liquid nitrogen at a stable temperature.

H. Tsukamoto
I don't know about liquid nitrogen, but compressed-air cars are extremely good devices for taking the kinetic energy created when the car stops and converting this to mechanical energy. However, various innovations will be needed before all the electrical current produced when the car stops can be absorbed by the fuel cell. As to what we can do immediately, I suspect that if we were to load on a hydrolink cylinder, compress all the air when the car stops, use some of that pressure when the car is about to set off again, and then continue using it to charge the battery, we would be able to lift the overall energy density.

As for whether PHVs really would reduce CO2 emissions, given that they'll help to level out night-time electricity, it seems likely. You don't stop coal at night.

E. Yamaguchi
We were talking about this in the context of liquid nitrogen as an inert gas, but the same thing could be done with methane, which has a boiling point of minus 169 degrees, and in a fuel cell hybrid it would produce a highly efficient engine. It was my sense that a forum needs to be created where people from various fields can brainstorm right back at the basics and deepen discussion further.

Ihara
In terms of thermodynamics, nitrogen is chemically stable but becomes liquid with the addition of work. However, I don't think this is practicable. The only thing that might be possible is to bring in that work from natural energy, waste heat, or other energies. While the efficiency might be limited in this approach, it could still help to reduce CO2. A little exploration in this area could well produce a viable technology.

K. Hayashi
In fact, nitrogen is close to free in the U.S. at around 20 or 30 yen. It's three times as costly in Japan, but a lot is also being thrown away, which suggests that if demand increased, the price would drop further. However, that's just the price issue; we also have to gauge how much primary energy has been used up to that point. If the current level of efficiency could be boosted a little further, the rough estimate is that it will be comparable or better than in current gasoline-driven cars, but a final confirmation hasn't been made as to how much primary energy is needed to make nitrogen.

I personally believe that compressed-air cars have greater possibilities than liquid nitrogen cars. At the same time, I have not been working with pistons in my research at the university, and putting liquid nitrogen in a piston system could produce rather interesting results. In other words, because the pistons compress the liquid nitrogen and raise the temperature, the consequent expansion of gas could achieve more efficient motion than in a turbine system.

Ihara
To make that energy, you have to add work, and the amount of work becomes the fuel energy. To achieve 100 percent efficiency in the energy conversion on top of that isn't realistic, so the more times you carry out the conversion, the greater this efficiency falls. However, if we were able to input first-use natural energy, this could serve as a CO2 countermeasure. Without it, given the current situation, we're going nowhere no matter how much efficiency is improved.

K. Hayashi
My initial position is to put aside such issues and start with how far the car will actually run, but I do think that I'll be able to boost efficiency and make improvements. But as you say, we do need to think about other means of energy input.

E. Yamaguchi
We shouldn't complicate the discussion here with technical issues related to primary energy. I'd like to proceed with discussion on the basis of the boundary condition that an optimal mix has been achieved for our primary energy.

Ishikawa (Toyota)
In all these cases—fuel cells or batteries, efficiency or whatever—are we going to link the discussion ultimately to what energy will be used? Or are we going to designate some form of energy as the optimal choice and discuss what kind of system would be required to use this?

E. Yamaguchi
They're dealing with primary energy in Session 1. Here I want to focus on what would be the best transportation system in terms of car transport. I don't believe that the Otto cycle can be the penultimate engine; what do you think?

Y. Nishiguchi
Dr. Yamaguchi thinks that the Otto cycle is not the answer. What are the views of those of you who are actually involved in car manufacturing?

Ishikawa
Cars currently have gasoline engines because of gasoline's extremely high energy density, but I think we will have to start looking beyond petroleum. From an automaker's perspective, however, when you ask what would be the optimal energy device, there are big cars, small cars, all sorts of cars, and I think the optimal energy device will differ accordingly. For example, both electric cars and air engines may well be feasible if we're thinking about cars smaller than that of the current light motor vehicles.

E. Yamaguchi
I'd like to move on to telecommunications infrastructure. Are there any comments on Dr. Morikawa's presentation?

Hasegawa
Discussion so far has been premised on the car, but I think we need to look at transportation beyond the car. What car do we actually need to operate in what situation? What is the optimal form of transportation? Dr. Morikawa talked about the "ubiquitous" concept, and I think discussion of what ubiquitous means in the case of transportation is extremely important in terms of addressing the big picture. Discussion about kinds of transportation infrastructure needs to be located within such a strategy to avoid ending up with no more than incredibly efficient cars that are able to run, for example, 1,000 km on a single charge, but which are entirely unnecessary.

K. Iwase (Ministry of Education, Culture, Sports, Science and Technology)
And even before that, there is the question of relocating various industries and cities. Thinking not just in terms of energy but also the resource cycle, will the one-way flow of resources transported over long distances continue to allow for a viable civilization?

Hasegawa
I think using batteries for load leveling is an excellent idea. When I went to Rome last fall, the University of Rome people were thinking about something interesting in the way of fuel-cell electric cars. Their approach was to make optimal use of whatever had the greatest efficiency. In the case of both fuel-cell electric cars and EVs, once the necessary platform is in place, further "upper-level" changes are easily made. The University of Rome concept in fact has a multiple cabin system. One cabin is designed for commuting and can carry a family, while in the afternoons after the commute, the same vehicle with a different cabin can become a lightweight truck and carry goods. In the evenings, it turns into a microbus so that it can carry more people. Finally, it becomes a small car to carry the family back home.

Ihara
A good transportation system should put virtual space vectors on a screen, which would then be used to decide how to shift traffic as a whole and in groups. The most serious problems presented for such a system would probably arise directly from the human factor—what people like and don't like—which is a very fundamental issue.

Morikawa (The University of Tokyo)
You're quite right, and that's where people from the arts often shake their heads at engineers. However, many things that people didn't originally think were particularly necessary have become very widely used. Most people initially thought that mobile phones and video recorders weren't particularly necessary. That's why the development of something new requires a particularly strong vision.

Ihara
People disliked those devices because they thought the information might leak out. In other words, one problem is security. I think that's the key from a technological perspective.

Amano (Toyota)
In that context, I was responsible for having the "Welcome, valued customer" system put into Lexus outlets. The idea is that when a customer buys a car, we get the customer's permission to register their electronic toll collection ID number so that we can raise our service level, extending the same kind of treatment enjoyed by customers at luxury hotels that greet their regulars by name.

But you have a very good point. When considering transport, in the case of goods, you just have to ensure that they are carried from the point of origin to their destination as efficiently as possible, and you can determine the manner of transportation with the greatest priority on rationality. However, when it comes to people, no system is going to take hold unless it delivers people what they want in terms of convenience and emotional satisfaction—whether someone gives up driving and instead travels on public transport, for example, or chooses a particular type of car—which are also choices that will differ according to purpose.

E. Yamaguchi

Finally, I'd like to ask Mr. Watanabe to talk to us about what auto manufacturers are doing to build a sustainable society.

Toward the Realization of Sustainable Mobility

Hiroyuki Watanabe

The U.S. Bureau of Mines says that median peak year for oil production will be 2037, or in a worst case scenario, 2026. Last year when I spoke to Mr. Jeroen van der Veer from Royal Dutch Shell plc, he said that world energy demand would double by 2025, with easy oil drying up and leaving only hard oil. In other words, only oil with a high carbon content will be left, making it impossible to achieve the CO_2 reductions that we're chasing. This year, the International Energy Agency announced that oil production will peak within the next 10 to 20 years. Every year the forecast moves a decade closer, which is an alarming situation.

Biofuel technologies certainly merit thorough investigation, but combining all the bioethanol from agriculture and garbage would apparently only produce 19 EJ. Given that we can probably use another two percent from thinning forests, etc., which would also amount to 19 EJ, we're looking at a total of 38 EJ. The total energy currently used by cars is 65 EJ, and this is expected to grow to 150 EJ. Evidently, there will be limits to what we can do on biofuels.

In the meanwhile, Sumatra's native forests are steadily disappearing to make way for plantations, and are expected to vanish entirely in 2010. If we're going to use biofuels, we need to be able to trace their origin and develop a good certification system so as to prevent Sumatra's plight being repeated around the world.

We're trying to do something surprisingly simple—to use electricity to power cars—but the problem is how to create that electricity. I think that primary energy too needs to be discussed, but I'm reassured to find that this is being covered in another session. I'd like to pose this issue. If all cars were to be converted to electricity and powered by nuclear power plants, we would need 15,000 to 20,000 reactors. As this seems unlikely, what other technologies, sciences, and ideas do we have that could be pursued instead?

Cars in the future will increasingly be electricity-powered or hybrids. These will include plug-in hybrids, fuel-cell hybrids, and electric cars. It is also possible that electric cars too will be hybrids that draw energy from both batteries and the grid. Ubiquitousness will be introduced. And because electric power will make the new vehicles extremely easy to control, we will move in the direction of autopilots. In other words, cars will become robots.

The Lexus hybrids run faster than six-liter models and have the same fuel efficiency as three-liter models. Moreover, because they are electrical, they run extremely smoothly. What hasn't been discussed here so far is dynamic range, or how fast the car can accelerate from a standstill to the point where it needs a lot of power. Because energy conversion technology can't be used in cars, the introduction of hybrid cars will make great improvements in this aspect of performance.

To what extent can plug-in hybrids be used to reduce CO_2 emissions? Taking the Prius as 1, Japan's CO_2 would drop by 13 to 15 percent, but CO_2 levels wouldn't fall in the U.S. or the UK. They would decrease by around 50 percent in France. This is because the extent of the reduction is dependent on the particular national power mix.

Harking back to the discussion on batteries versus fuel cells, I think the answer is, as Mr. Ishikawa noted, that there are various types of cars, and for some cars fuel cells will be better, while some models will do better on electricity. Mankind changed the carriage engine to make a car. We're still in that carriage civilization. A single person or a single good travels from door to door, families travel together, and in none of this is there any adjustment for different situations. Accordingly, I don't think we need to think about the car in conventional terms. If one person is travelling, a small car is fine, and where a family is travelling, they could take a wagon. It doesn't even have to be a four-wheel vehicle; it could be a Segway; or ultimately the vehicle could be roboticized and become something you can carry by hand. Various choices would also emerge in terms of engines for these vehicles.

It was mentioned that fuel cells were flawed because they freeze at low temperatures, but in terms of technology, we currently have them operating smoothly at minus 37 degrees. In terms of the continuous cruising range too, we already have a vehicle that can run up to 780 km. The problems with fuel cells, then, are how to make hydrogen, and the large amount of CO_2 emitted in parts production. The reason that so much CO_2 is emitted is that a lot of CO_2 is still emitted in the process of creating hydrogen from methane gas, and because electricity is used in the production processes for carbon fiber and aluminum parts, etc.

Therefore, we need to resolve the issue of which primary energy to use to produce electricity before we will be able to resolve these other issues, and this will ultimately impact on the cost of fuel cells. However, I do think that fuel cells are extremely well-suited for such vehicles as 10-million-yen buses and trucks for long-distance transport.

Car efficiency is, of course, the drive created by the energy supplied, or tank-to-wheel, but engine makers ignore even the highest running resistance. This is because systems are developed within the well-fenced academic discipline of thermodynamics. Discussion of fuel from a well-to-tank perspective was originally launched jointly by Argonne National Laboratory and General Motors Corporation. I think we should further add consideration of what speed an object of a certain weight will be travelling and how much energy will be needed for that. In other words, we should be aiming to carry many things fast using minimal energy.

For example, the energy used to operate a Tundra in Los Angeles is almost double that of an average car in Tokyo. But compared to the 20 km average speed within Tokyo, you can travel in Los Angeles at around 34 km per hour, so where

Tokyo is 1, a Tundra pickup in Los Angeles will be around 0.86, which is not a big difference. In other words, no matter how good the car itself, its travel performance in Tokyo will be poor. Now, let's take the same concept across to a transport society seven times that size. A 1,200 kg Corolla could carry a family around the suburbs. When they go to town, they could use a more convenient 300 kg car, or they could ride on a big 30-person bus or tram. Within a 2 km radius, they could cycle or walk. In the future we will need to create a transport society that incorporates these various combinations.

What we need to do, then, is come up with various technological innovations that have low energy consumption, aiming for weight reduction, automatic operation, platoon driving, and plug-in hybrids. We also need to change the shape of towns, building in intelligent transport systems (ITS), transportation demand management (TDM), and the use of buses and trains rather than cars for commuting. These steps need to be pursued. Further, we should create a transport society whereby goods and people travel using the optimal combination of the various means of transport.

To this end, 22 Japanese firms have banded together to create the Council on Competitiveness-Nippon (COCN) to make various proposals to the government. The COCN has launched a project toward halving CO2 emissions and eliminating traffic fatalities, which have been on the rise. Specific issues include improving urban transport (reducing CO2) and distribution reform. Trucking in Japan currently costs around 2.5 times as much as in the U.S., while rail transport costs seven times as much.

The kind of mobility performance I outlined above cannot be achieved with the technological innovation on an individual product basis that has been pursued to date. Instead, we need to pursue the following reforms: (1) changing infrastructure; (2) introducing new technologies like ITS; (3) changing cars themselves; (4) having the public and companies undertake voluntary action; and (5) simultaneously modifying policies and regulations. We want to undertake three sets of field trials in model cities by 2020. We are considering conducting competitions in this regard among the model cities.

For example, in pre-crash safety systems, when the car is about to crash, a break assist system goes into standby, the slack in safety-belts are taken up, and when the driver steps on the brake pedal, the oil pressure shoots up more quickly than usual. Lane-keeping assist systems set up light resistance in the steering wheel when the driver diverges from road lines. Radar cruise control is designed so that, when, for example you are travelling at 80 km/h on the motorway and another car is ahead of you, your speed is adjusted to maintain a fixed distance between the two cars. In other words, we already have the necessary longitudinal control technology for platooning. The next step will be to add in lateral control, as well as the vehicle-to-vehicle communication that Dr. Morikawa was talking about, so that braking information from the car in front is communicated to the car behind, giving the following car prior knowledge of the road friction coefficient and thus preventing rear-end collisions. Combining these various components could also open the way for platoon travel.

Questions and discussion

Okayama (JST/CRDS)
In your presentation you talked about a car small enough to carry in a bag. When I was in India last year, I really felt the limits of the road as a type of infrastructure. In considering the various modality mixes, if we break away from the idea that cars have to travel on roads, what potential obstacles do we face in terms of mechanisms?

H. Watanabe (Toyota)
I think that in the world of transportation, the Prius might be the last of the single-technology innovations. For example, if we want to bring in platooning or autopilots, we will first have to win public sympathy and understanding. We will also have to change the law, and infrastructure too will need to be altered to some extent. Because this can't all be achieved at once, we need to undertake field trials, release information on the results, and upgrade technology, while also ensuring public participation and fostering understanding. These steps will be crucial in advancing innovation. In other words, resolving the CO2 and energy issues that we currently face will require compound innovation.

E. Yamaguchi
It has long been said that the ideal means of transport would be a centipede device that could walk off-road. Is Toyota doing anything along those lines?

H. Watanabe
I think robots are the answer when it comes to being able to go anywhere that people can go. Robots don't need to have a human form, but their functions can be upgraded so that they don't make the kind of absent-minded mistakes that people make. They also need to be able to provide full support for the elderly and the physically challenged.

Y. Nishiguchi
If we are looking at car usage from the perspective of CO2, surely the correct usage will gradually become apparent. For example, on U.S. highways, if a vehicle is carrying two or more people, it can travel smoothly in the left lane, providing an incentive to carry more passengers. Then, if petrol prices rise any further, people will naturally begin to use cars only when it's really necessary.

H. Watanabe
With California's car pool lane system, the state requires firms to have a certain number of their employees use that lane. Recently, there are also apparently lanes that can only be used by vehicles with three or more passengers. It's the driver's responsibility to find two more passengers by advertising on a certain website what time and where they will be going and asking if anyone wants a ride.

I. Yamamoto
The amount of CO2 emitted in Japan is actually decreasing. Looking at how to change things in China and India would

be far more effective. On the other hand, the car market in China and India is absolutely huge. I think that designing cars for these markets, the social infrastructure included, will be a major theme over the next 10 or 20 years.

The quickest technological means would be to introduce hybrid cars, and I think that if possible, the fastest way would be something close to an electric car. Surely the practical approach is to bring down the cost of these as far as possible and encourage market penetration.

H. Watanabe
I entirely agree. We have a plant in Bangalore, where they are currently experiencing huge traffic jams. The situation wasn't as bad when we first set up the factory. When I asked Chair Rajendra Pachauri of the Intergovernmental Panel on Climate Change what should be done, he said exactly the same thing. Firstly, we have to go beyond the foolish approaches that the developed countries have pursued and introduce ideal systems, as they've done in Nantes. Secondly, we have to shift from the Western fixation with big cars to acceptance of smaller cars. In India they have auto-rickshaws, but these need to be made safer and more environment-friendly. While it might be extremely difficult to create this kind of paradigm, even in the U.S. General Motors at one point decided that "small is good" and switched for a while to front-engine, front-wheel drive, creating small cars. So it's not something that can't be done. Japan is leaning a little more that way, which is why light motor vehicles are selling.

H. Tsukamoto
I'm in a car for an hour every day commuting in Los Angeles, and I also travel two or three hours by car when I go on business to San Diego and other cities. It would be great if I could cut the amount of time that I spend in gas stands entirely, or at least reduce it to a third or a quarter. I don't care if I can't see outside. I only need a phone and Internet access.

Tatsumi
There are various different ways of reducing energy-related CO2 emissions. But I do think that electric cars—looking at how to incorporate electric energy—are a viable route. So I think that before we make the shift to fuel cells, first we should put batteries in cars and work on getting electrical energy into plug-ins and other hybrids, incorporate electrical energy from biofuels, bring down the cost, and get these cars out on the roads.

H. Watanabe
Electric cars are not only environmentally-friendly, but they also accelerate well and run quietly and comfortably. So once someone has ridden in an electric car, I think there's no going back. In making electric cars, or battery cars, there's little sense in sticking with traditional car concepts. If we can't come up with something like a lithium-air battery, we probably aren't going to achieve a 500 km cruising distance. But do cars need to retain their current look and run 500 km? If we change our concept of what a car should be and do, I think various possibilities would open up.

K. Niwa (Organizer)
Engaging in this discussion at GIES is, I think, extremely significant. What message do we want to contribute from GIES in the following session? I think that a forum needs to be created for global cooperation in particular among manufacturers, the researcher community, and countries, etc., toward changing old paradigms. It would be great if we could get something moving from this occasion, produce something concrete, even if it's only small.

In that sense, is there anything from the initiative that Mr. Watanabe introduced yesterday, Mobility 2030, which could provide a clue?

H. Watanabe
Mobility 2030 was discussed in 2004 at the World Business Council for Sustainable Development, and was completed at that point. However, I do think we should take the next step. In that sense, the Cabinet Office is addressing transport issues as part of its projects to accelerate social returns, and I think some interaction there would be possible, but it would be preferable for this to happen on an international level.

E. Yamaguchi
When GIES 2007 took place in June last year, air pollution was the central theme, and Mr. Watanabe was a central figure in creating the East Asian alliance initiative. I wonder if this time too we could create some type of alliance or consortium that builds on our discussion and which also covers CO2.

H. Watanabe
If Japan wants to learn more in this area, I think Japan's high-tech industry should get together with front-running places like Nantes and Freiburg in Europe to discuss a mechanism combining their respective strengths.

E. Yamaguchi
Basically, the kind of forum that we need is one that would slot between input and practice at the stage of producing final ideas for the purpose of brainstorming on the whole picture. It would obviously have to be an open and integrated forum. What we need to create is not a closed system, comprising only majors like Toyota, Nissan, and Honda, for example, but rather a forum in which various parties can participate, creating concepts, sharing knowledge, and creating de facto standards. I also think that we will ultimately need to create some truly innovative business model like V2G. We had a very lively discussion today. I hope we can carry that sense of excitement forward into some form of action.