Creating Safe, Secure, and Environment-Friendly Lifestyles Through i-Energy

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1. Introduction

Until now, telecommunications have sought to provide convenience, fun, and ease of use. It is well understood that information and communications technologies, or ICT, have achieved these objectives, but I believe that this is just the first stage of telecommunications. We have recently entered the second stage, and future ICT should explore new social infrastructures in the twenty-first century. This is the message of my presentation today.

2. Physical real world and cyber network society

Until the twentieth century, the structure of society was such that most activities were in the physical real world. In the second half of the twentieth century, particularly toward the end of the century, the cyber network society was developed. In the real world in which we live, all activities have been created based on "natural" physical laws. For example, all mechanical devices and sports activities are designed taking gravity into account.

Activities in the cyber network society, however, are determined by "artificial" laws, regulations, and other rules. Because of this, standardization by organizations such as the International Telecommunication Union is crucial to realize well-coordinated social activities. How to design rules and how we comply with them in the cyber network society will be important issues in the future.

In the twenty-first century, the real world and the cyber network society will exist side by side; people will have to live in both environments. The crucial problem then will be how we can develop social infrastructures by bridging the physical real world and the cyber network society. My idea is as follows: in the real world, we have flows of goods, people, and energy, while in the cyber network society there are flows of information. I believe that if we can link and integrate these flows, we can create new social infrastructures in various fields (Figure 1).

In what follows, I will first show several examples of such new emerging social infrastructures and then propose the concept of "i-energy," the integration of the electric power network and the information network to realize an environment-friendly society.

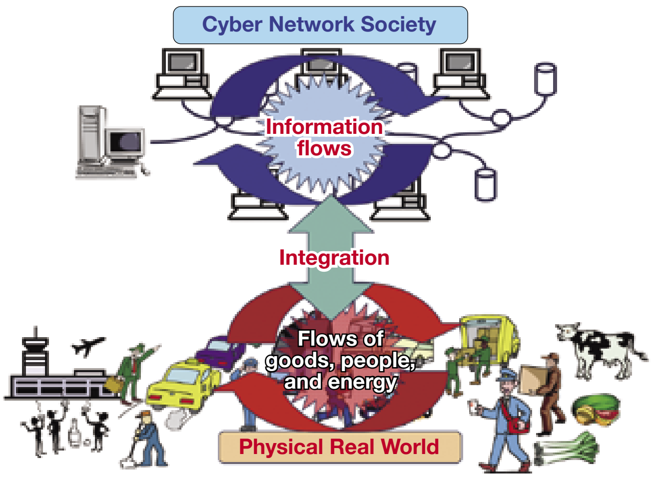


Figure 1 – Integrating dynamic flows between real world and cyber network society

3. Integrated social infrastructure – Example 1: Digitization of value

Although the integration of the real world and the cyber network society seems to be a future issue, it has already started. The first such example is the transformation of currency, securities, and other forms of value into electronic information (Figure 2). In the real world, value flows in the form of currency and valuable things like gold, but in the cyber network society, money and values flow as electronic numbers and drive food, oil, and other markets.

Authentication and security are major issues that must be addressed if the real world and the cyber network society are to be linked. There is a move toward adding biometric authentication functions even to bank cards, indicating just how important confirmation of the authority to move numbers has become.

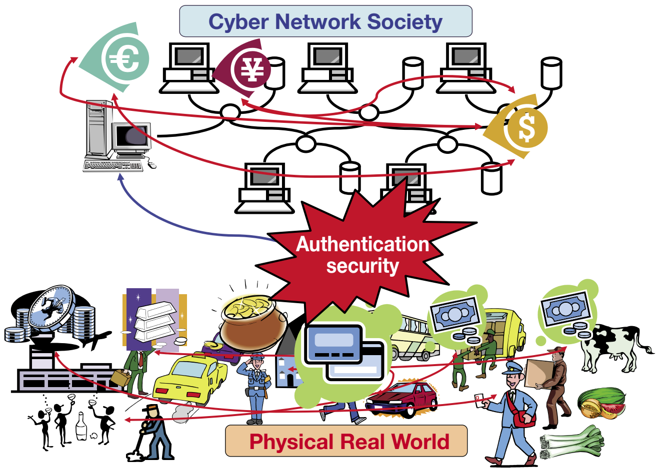


Figure 2 – Development of electronic economy through digitization of currency and securities

4. Integrated social infrastructure – Example 2: Monitoring and tracing flows of objects and people

The second example is the online real-time monitoring of locations of real world objects and people by attaching electronic tags to their physical bodies. This social infrastructure has been gradually deployed into our everyday lives and is called a ubiquitous world. Its applications include foodstuff traceability, child monitoring, and mobile phone traceability (Figure 3).

5. Integrated social infrastructure – Example 3: Digitization of human activities

The third example may be somewhat novel, but when people are involved in the cyber network society, we want to digitize our dynamic activities and see digitized versions of our activities. Its applications include wide-area traffic monitoring by sensor network systems and understanding physiological body conditions by wearing a wristwatch sensor or swallowing nano chemical sensor devices. We are attempting to understand dynamic human activities in real time (Figure 4).

About 10 years ago we started developing a three-dimensional video system. What we first made was a system with many cameras installed in a room, and each camera cooperatively tracked a moving object in the room. When one camera discovered a person coming into the room, the information concerning the person's location and appearance was conveyed to the other cameras via an information network, and then numerous cameras were able to track and observe the subject from a variety of view directions. Later we used this technology to develop a three-dimensional video system that recorded human actions (e.g., dances) as full three-dimensional images. Since the images are three-dimensional, the viewpoint can be changed freely as you like.

Today it is possible to record high-definition images and produce three-dimensional images with a resolution of one to two millimeters. The volume of data is extremely high and so research on compression is being conducted. This is not the main topic of today's discussion, but I wanted to mention it briefly.

6. Human communication bridging between the Cyber Network Society and people

A new situation that is currently taking place in the cyber network society is the rapid accumulation of an extremely large amount of distributed information sources on the Internet (that is, the Web). It has long been said that Japan, which lacks natural resources, must develop its human resources. However, when considering Japan's future, it is also necessary to discuss what types of information resource strategies Japan should develop.

The company that has been the most successful in the world in turning information resources into a business is Google, and I think the best example of this is Google Earth. The consolidation of the Earth's great store of geographic information has had a tremendous impact, and many people are engaging in a wide range of activities using Google Earth, both out of interest and for business purposes.

Various agencies, as well as the Japanese Ministry of Internal Affairs and Communications (MIC), are developing technologies for searching and analyzing information accumulated on the Web. For ordinary users to effectively use these information search and analysis technologies,

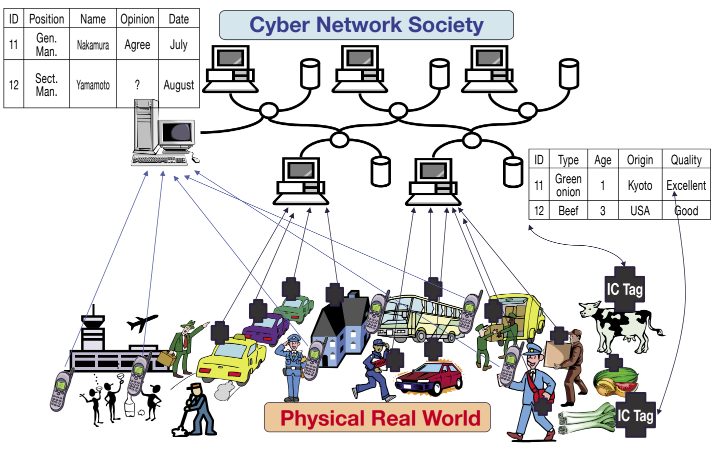


Figure 3 – Monitoring flows of goods and people with E-Tags

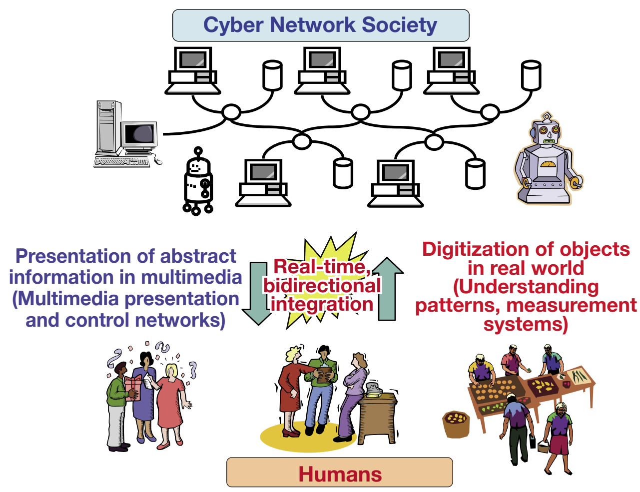


Figure 4 – Digitizing human activities

however, page ranking is not enough and user-friendly guidance and navigation functions need to be employed: the information sources on the Web are just too large, mutually related, and sometimes misleading. Rich interactive human communication channels should be introduced to bridge between people and the Web and enable them to deeply understand the meaning of information (Figure 5).

Previously 'human interface' meant a method of making computers easier or more fun to use, but in the future this should be expanded to human communication, which means functions that facilitate efficient communications with the cyber network society. In other words, our focus should shift from "knowing" things to "understanding" things. While people can retrieve a large collection of information from the Web, they have to digest it to establish understanding. We believe human communication should help people to digest.

In particular, as society becomes more developed, rules and regulations in it become too complex for ordinary people to understand the meaning. Managing such a complex society requires social leaders to implement mechanisms that enable ordinary citizens to understand the social systems. We believe human communication should play an important role in developing such mechanisms. That is, distributing manuals or leaflets to people will not be enough, and instead interactive communication explaining the social systems and answering individual questions will be needed.

To make people understand, rich communication functions need to be employed; text and voice communications alone are not enough. Various non-verbal communication functions should also be employed by sensing levels of knowledge and situations of people (Figure 6).

Natural communication has been discussed in various academic forums over the years. Realizing natural communication requires sensing and providing various information that appeals to the five senses. Various research on such multi-modal communication is being conducted. In my lab, we are conducting research on "the sixth sense." Here, the sixth sense implies an issue of dynamics, and we are focusing on dynamics in communication. In what follows, I will give an overview of our recent research.

7. Researching sixth sense

The first research topic concerns recognition of facial expressions. Our focus is not to classify mental modes, such as laughter, anger, sadness, and so on, but to discriminate between very subtle facial expressions, such as intentional and natural smiles. To this goal, we analyzed dynamic motion patterns of various elements of the face, e.g., eyes, mouth, nose, and so on. Then we extracted features characterizing the dynamics of these motion patterns. We found that intentional and natural smiles show very different dynamic features which we can distinguish easily. There are, of course, individual differences in the ways that people smile, and hence we observe differences in individual dynamical features, so these personal characteristics should be learned a priori. With our method, it will become possible for a computer to identify whether a person is really smiling or just being sociable (top left in Figure 8).

The next topic relates to the dynamics in human speech conversation. We analyzed temporal intervals between the end of an utterance by one person and the following utterance by another in *manzai* (Japanese standup comedy usually done by a pair of persons, a straight man and a stooge). In our naïve understanding, there is some pause (silence) between the end and start of utterances. But what we found is that in about a half of the turn takings, the follower started speaking before the predecessor stopped speaking. That is, in human speech conversations, utterances are often overlapping, which makes participants feel "connected" and conversations continue naturally (Figure 7). Another interesting thing we found is that as the dialogue gets more excited, there emerge more frequent overlaps. This serves to enhance the sense of excitement.

Our findings show that we human beings cannot communicate with current computer/robot systems because they respond/react only after a user gives a command and hence no overlapping interactions can be realized. Interactions without overlapping make people feel "disconnected" and sometimes irritated. If you doubt our results, why don't you put in a pause every time you speak when speaking to your wife or husband? The response will likely be an angry one – "Are you mocking me?!" (*Laughs*)

The third topic concerns multi-modal synchronization.

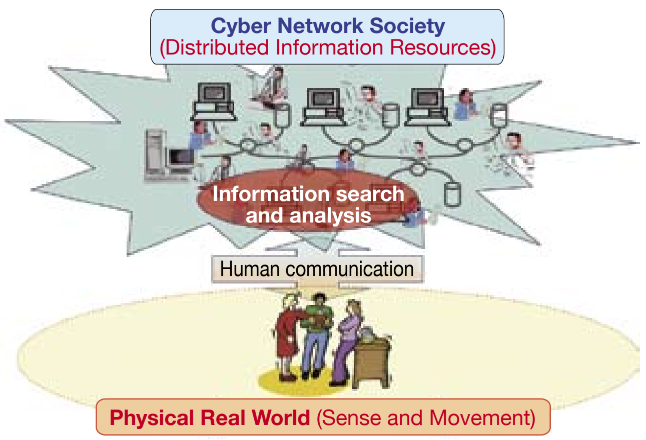


Figure 5 – Human communication for bridging between people and web

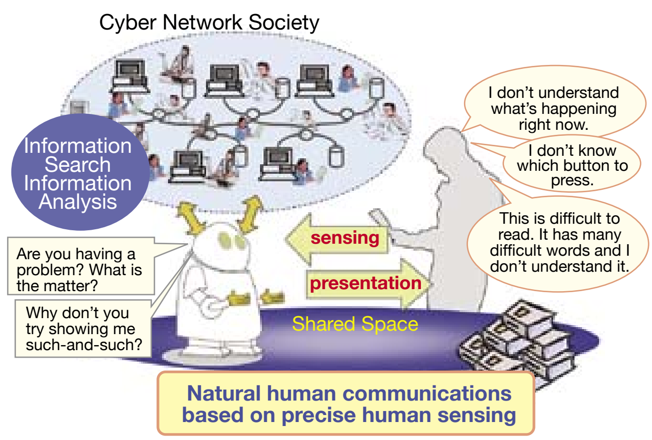


Figure 6 – From Knowing to Understanding

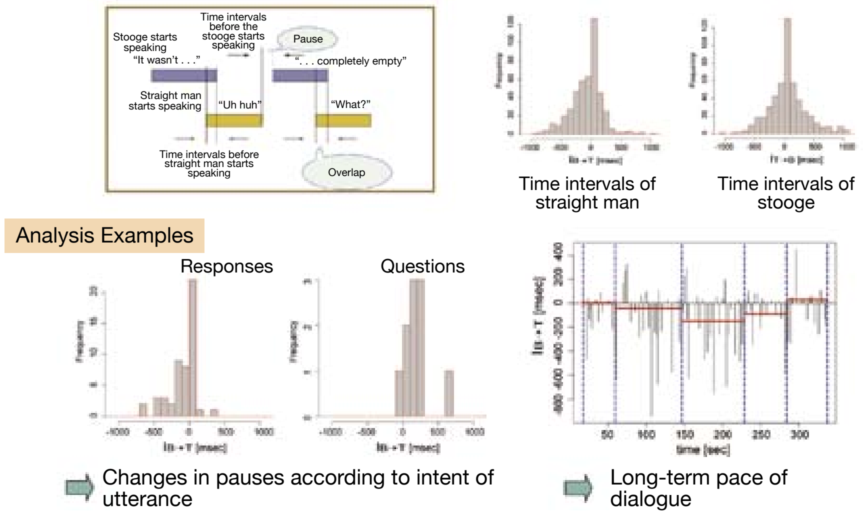


Figure 7 – Analysis of dynamic structure of comedic dialogue

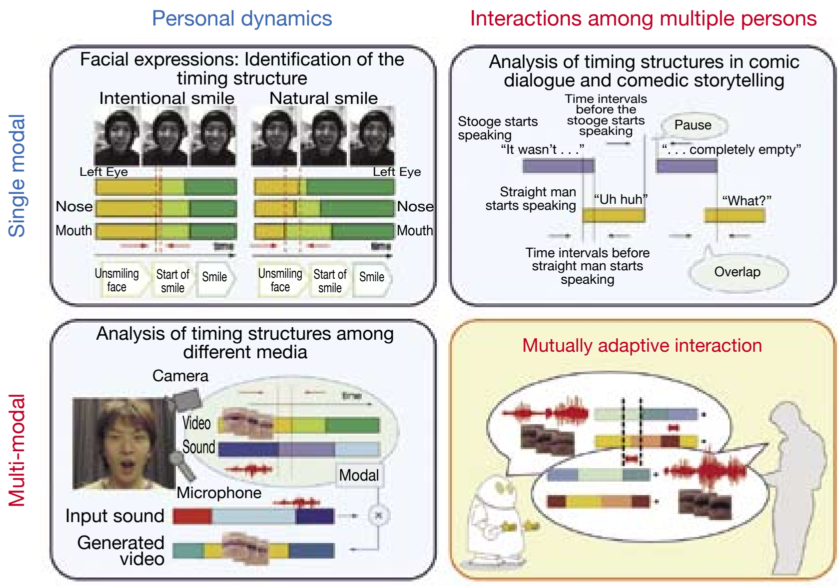


Figure 8 – Research of dynamic interaction in human communication

We analyzed temporal synchronization between mouth motion and voice sound when a person speaks. The mouth moves and sound is produced in synchronization with its motion. We developed a mathematical analysis method to model such multi-modal synchronization. If the synchronization structure is learned in advance, we can generate a mouth motion video well synchronized with a given sound signal. That means that sound signals can be transformed into video data.

It would also not be that difficult to adjust actors' mouth movements when anime and Japanese dramas are translated into English or French, for example, so that they match well the translated word sounds (bottom left in Figure 8).

8. Information concierge

The ultimate goal of our research is to create a system that can communicate effectively and naturally with people. Right now, we are developing what we call an information concierge system with a large display. The system uses sound and video to probe and estimate human mental states and continues long-lasting communication by adjusting timing to the mental states (bottom right in Figure 8). We are conducting research and development on this type of "information concierge" system jointly with the National Institute of Information and Communications Technology (NICT).

9. i-Energy: Integrating electric power and information networks

How should telecommunications networks support our social activities? This is the topic of my presentation today. As I said at the beginning, my basic idea is that we must approach this issue from the position that telecommunications networks are not simply for convenience and fun but are absolutely essential for a sustainable society.

I am proposing the "i-energy: integration of electric power and information networks" concept as an important future social issue. I participated in the Study Group on ICT Policy for Addressing Global Warming conducted by the MIC from 2007 to April 2008. The ministry has been working for some time to contribute to the prevention of global warming, mainly based on the idea that ICT can reduce the physical movement of goods and people and consequently reduce energy consumption indirectly. We promoted this action one step further and proposed that ICT can be used to develop an energy- efficient and environment-friendly social infrastructure by directly managing the flow of electric power.

While it is reported that the use of ICT will reduce carbon dioxide emissions in the near future (Figure 9), it appears that the reduction in energy consumption will be modest. To accelerate the reduction, we are proposing a new approach based on the concept of the integration of dynamic flows in the physical real world and the cyber network society (Figure 1). To put it another way, in the next 40 to 50 years electric power networks in the real world will undergo revolutionary changes similar to the one we saw in telecommunications networks in the twentieth century.

For example, technologies equivalent to PCs are being developed in the world of electricity, such as solar cells and fuel cells. These are extremely small-scale "personal" power units that are being widely distributed in homes. Today, each house that uses a solar cell and/or other such power sources buys and sells electricity from/to an electric power supply company, a central supplier. Then, what happens when the number of houses with solar cells reaches thousands and millions? Electric power networks will become unable to handle such largely distributed "unstable" power units. For example, when the weather is good, more electric power is generated by solar cells, power becomes excessive, and the excess can be sold to the electric power supply company. To sell electric energy, the voltage of the generating line is measured and the voltage on the inside is raised by, for example, one volt more. This causes the energy to flow from a house to the generating line. Since the weather is good, its neighbor also wants to sell excess electricity. Then, since the voltage of the neighboring house was already raised to 101 volts, this house has to raise the voltage to 102 volts. If 10 houses do this, the voltage is raised to 110 volts. If 100 houses sell electricity, the voltage is raised to 200 volts. This in fact does not occur, but currently this level of control is all that is available. In other words, no intelligent electricity flow management is implemented.

The capacity of the generating lines provided by electric power supply companies is generally extremely high, and there will be no impact from the addition of the solar cells of one or two households. If everyone installs solar cells, however, current electric power networks could not handle the load. If there were any electric power supply company representatives here today, they may become angry, but the capacity of the electric power infrastructure of Japan is not that high. As solar cells and wind power become more common and are connected to networks in large numbers, the flow of electric power will change, and hence the electric power network architecture should be changed in the twenty-first century just as telecommunications networks changed to the Internet in the twentieth century.

In addition, as the use of electric and fuel-cell cars expands, there will be frequent transactions involving energy. Under these circumstances, we should make telecommunications networks constantly monitor and control electricity flows in electric power networks. The "i-energy" concept represents a concrete image of the integration of these two networks (Figure 10).

Japanese industries are developing world-leading energy saving technologies. In contrast, consumers such as ourselves have been continuously increasing our electricity usage. From 1990 to 2004, carbon dioxide emissions by industry in Japan declined 3.4%, but emissions from offices and other commercial sites grew by 37.9%, and those from households rose 31.5%. There is little prospect that emissions will decline in the future, and there are few ideas for reducing emissions (Figure 11).

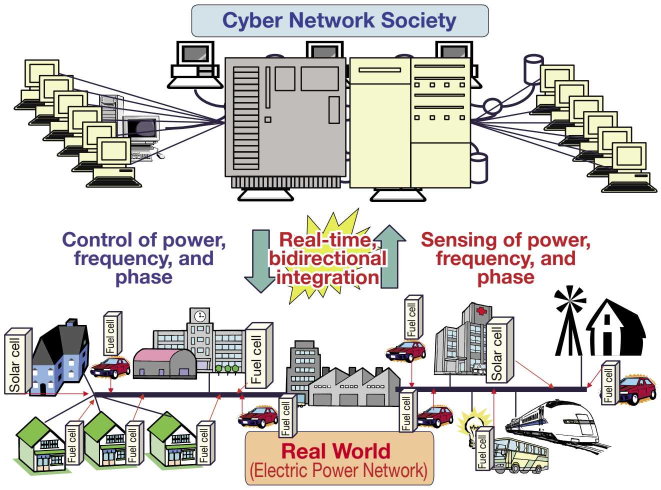


Figure 10 – Integrating Information and Electricity Networks

Figure 9 – Carbon Dioxide Reductions by the Use of ICT

Assessment Field	Use Scenario	2006		2010		2012	
		10,000 t CO_2	Percentage	10,000 t CO_2	Percentage	10,000 t CO_2	Percentage
Electronic transactions by individuals	Online shopping	198	0.1%	542	0.4%	712	0.5%
	Online plane ticket issue	2	0.0%	5	0.0%	6	0.0%
	Sale of travel coupons at convenience stores	31	0.0%	60	0.0%	64	0.0%
	Installation of automated cash payment machines	261	0.2%	291	0.2%	319	0.2%
Electronic transactions by businesses	Online transactions	527	0.4%	767	0.6%	836	0.6%
	Supply chain management	532	0.4%	1,839	1.4%	1,839	1.4%
	Reuse markets	577	0.4%	1,154	0.8%	1,197	0.9%
Conversion to electronic format of products	Music	35	0.0%	114	0.1%	133	0.1%
	Video programming	15	0.0%	21	0.0%	25	0.0%
	PC software	11	0.0%	53	0.0%	61	0.0%
	Newspapers and books	4	0.0%	91	0.1%	95	0.1%
Movement of people	Telecommuting	30	0.0%	50	0.0%	63	0.0%
	Video conferencing	105	0.1%	194	0.1%	305	0.2%
	Remote management	5	0.0%	5	0.0%	5	0.0%
Intelligent transport systems	ITS	308	0.2%	370	0.3%	401	0.3%
Electronic government	Electronic applications	0	0.0%	2	0.0%	2	0.0%
	Electronic filing (tax returns)	0	0.0%	8	0.0%	8	0.0%
	Electronic filing (online receipts)	0	0.0%	1	0.0%	1	0.0%
Energy management	BEMS, HEMS	468	0.3%	730	0.5%	730	0.5%
Total		3,110	2.3%	6,297	4.6%	6,802	5.0%

Note: Percentages in the table represent the percentage of Japan's total greenhouse gas emissions in 2005.
Source: Ministry of Internal Affairs and Communications, Study Group on ICT Policy for Addressing Global Warming

10. Building home networks for real-time electricity flow monitoring

I developed a practical plan that aims to realize a drastic reduction of electricity consumption in homes and offices and which will change the electric energy social infrastructure in four phases.

The first phase is the development of an electricity sensor network at home. We have built a network for monitoring electricity flows in the home. Wireless LAN and/or PLC terminals with electric power monitoring functions are attached to all appliances at home, which monitor electric power consumption by appliances in real time to create a database of electricity consumption patterns. This will allow for the safe and secure monitoring of human activities in the home.

For example, if an outdoor security light turns on and off at two in the morning, we know that someone is prowling around. Or if the lights are not turned off for a long time in the bathroom, we can ask if everything is all right. Since many appliances are controlled by humans, we can see human activities by analyzing their electricity consumption patterns: e.g., usage patterns of a hair drier change from person to person. It will be possible to monitor people's activities without any basic loss of privacy (Figure 12).

It will also be possible to provide consulting concerning additional attention to energy conservation. In addition, it will be possible to detect irregularities in the electricity distribution system, such as short circuits. This will help prevent fires. Moreover, the unusual electricity consumption pattern of an appliance leads us to check if it has any problem.

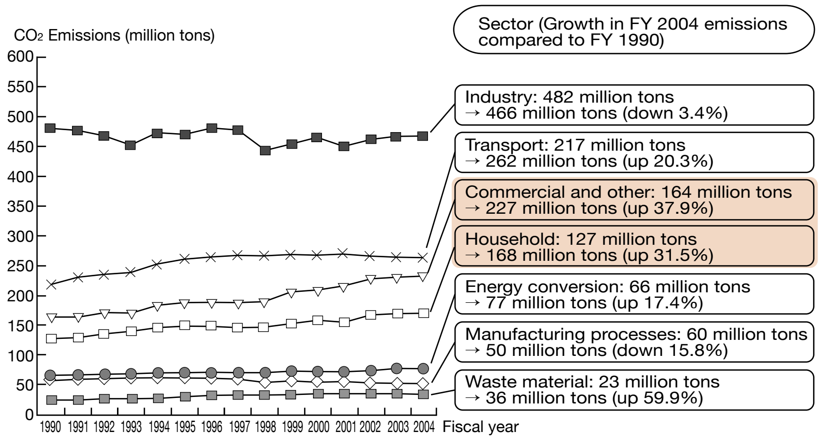
11. EOD: On-Demand Electric Power Network

While the first phase system, the network of electric power sensors that I just described, already exists, the novelty of our plan rests in what we are proposing as the second phase system, "the on-demand electric power network," or "EOD" (Energy on Demand).

Currently, when you turn a switch on, the electric line is connected and the power immediately turns on. The on-demand network works quite differently. When a switch is turned on, a data packet requesting a certain volume of electric power is sent out. A power manager receives the on-demand request, determines whether to allow the power usage based on lifestyle patterns at home, prior conservation performance, residual energy stored in batteries, and other factors, decides whether to supply only 80 watts even though the request was for 100 watts, and only then allows the electricity to flow.

From one perspective, an electric power demand request is submitted, a negotiation takes place, and when the reply arrives the electricity turns on. Seen a different way, however, for that time, electric power is packetized and the beginning and end are closely monitored, so we can say that electric power is virtually packetized.

Note that EOD can be achieved by adding power control functions to existing power sensing modules (Figure 13).



Source: Ministry of the Environment, Annual Report on the Environment in Japan 2006

Figure 11 – Annual changes in carbon dioxide emissions

Phase 1: Short-Term Issues (practical application in 3 to 5 years)
Sensing devices with power sensors and communications functions that can be plugged into outlets will be attached to all electrical equipment. Electric power usage will be measured and analyzed in real time, consumers' activity patterns monitored, and consulting provided on energy-saving techniques.
Enhanced value of a completely electrical house

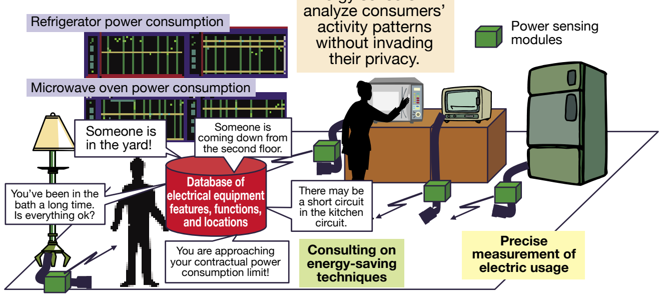


Figure 12 – Monitoring human activities through electric power sensing

Phase 2: Medium-Term Issues (practical application in 5 to 10 years)
Adding power control functions to the equipment mentioned above, various electrical devices, including power storage and generation devices, will be controlled over networks. Such systems will support safe, secure, and environment-friendly lifestyles by managing energy very efficiently, saving redundant energy proactively, and providing services to support autonomy in disasters and will support energy saving through flattening power consumption variations in society.

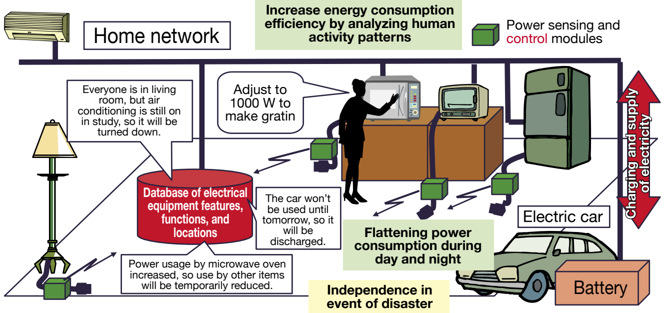


Figure 13 – Power management using on-demand power networks

Phase 3: Medium-Term Issues (practical application in 10 to 15 years)
Electric power generating equipment installed in each house will be used and household total energy management systems built. Priority control for power usage depending on sources of energy (i.e. coloring electricity) will be achieved.

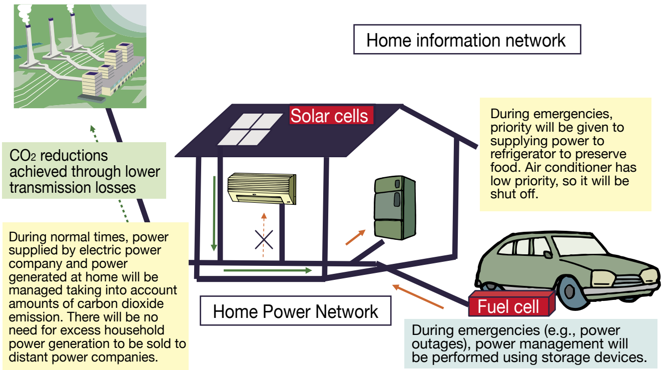


Figure 14 – Intelligent nano grid at home

Phase 4: Long-Term Issues (practical application in 20 to 30 years)
Homes in a local area will be linked by a network, individual power management systems integrated, and a local energy management system that can perform power transactions will be created. This will facilitate the development of social energy infrastructure (ultra-distributed power networks) that is efficient and resilient during emergencies.

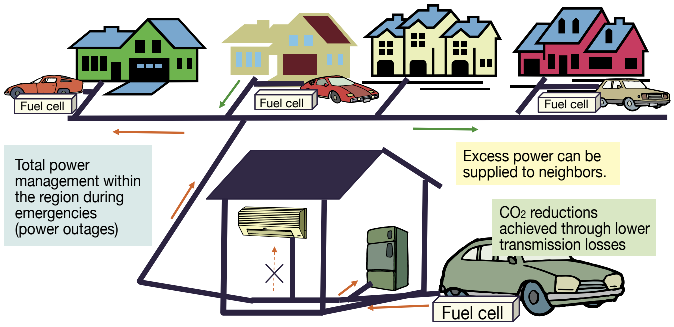


Figure 15 – Local area intelligent nano grid

12. Use of batteries

The most important component of the on-demand electric power network is batteries, with which the system can manage electricity over time as routers manage data packets using memories. While it may be an idea to buy batteries for the on-demand electric power network at home, why don't we buy an electric car? It seems unlikely that fuel-cell cars will be marketed in the near future, but according to some automobile manufacturers, electric cars will be on sale to the public in 2009. While electric cars do not generate electricity, they are in fact giant mobile batteries sufficient to support the electricity required for one full day in the home. A key point is the intelligent managing function of charging and discharging of electric car batteries, which will be performed by the on-demand electric power network at home (Figure 13).

Most offices have universal power supplies (UPS) to act as backups for their servers in the event of a power outage. Thus, the on-demand electric power network at offices can use UPS for power buffering. Because of security issues, moreover, recently many offices have been adopting thin clients that do not have local hard disks, and all activities on thin client PCs are monitored on a server. This makes it possible to manage electric power, including monitoring who is using how much power.

To achieve such power management, we have been cooperating with the NICT Keihanna Research Laboratories to create a prototype of a four-outlet power strip with a communications module and power sensing and control functions. With this device, the amount of electric power supplied to an appliance can be controlled continuously by controlling the phase of AC electric power.

13. Coloring electricity: Intelligent nano grid at home

The third phase system introduces power generation modules into the on-demand electric power network such as solar cells, fuel cells, wind power, and so on. The scenario is exactly the same as that for batteries described earlier except that the network colors electricity and manages it differently depending on the color (Figure 14). For example, nature-origin electricity, such as that generated by solar cells, can be used rather freely, while electricity whose generation process produces carbon dioxide should be saved strictly.

14. Regional cooperation

The final phase is the integration among these on-demand electric power networks in homes in a local area. People will buy and sell electricity to and from their neighbors over the local area on-demand electric power network. Like emissions credit transactions, this will involve money flows in business, and therefore solid management protocols that maintain consistency between energy sellers and buyers will be essential. If all houses and offices implement the on-demand electric power networks, which then are mutually connected across a country like the Internet, we will see a new energy business as well as a drastic reduction of carbon dioxide (Figure 15).

15. Flattening electric power supply

If the steps that I have outlined so far are implemented, what will be the impact on society as a whole? An electric car currently being considered for commercial use is said to have a battery that can store about 16 kWh of power. The typical household does not use 16 kWh of power per day.

Let's assume that a battery with this capacity is fully charged at night and used for appliances at home during the day. The cost of electricity at night is about one-third of that during the day in Japan, and so even taking into account charge-discharge efficiency, in a best-case scenario, a household could save 47,963 yen in electricity costs per year; even a low estimate would yield about 40,000 yen in savings. The effects of lower electricity costs will be seen directly in household finances.

As well as in each home, the large-scale introduction of batteries in society can realize a flattening of electric power supply. Electric power supply varies between day and night and the seasons. If this variation becomes flatter and proceeds with a flattening rate of 1%, 2.9 million kilowatts of electric power facilities will no longer be needed (although these figures are somewhat old). Moreover, the cost

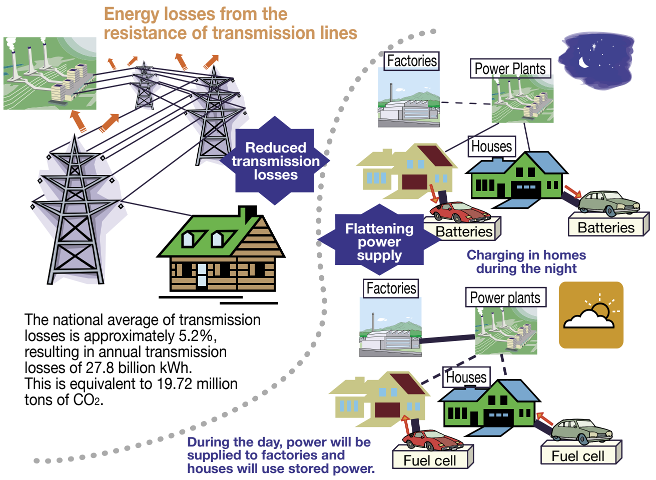


Figure 16 – Social effects of distributed energy systems

of electric power will become 1% lower, and hence electricity bills will fall 1%. It is also estimated that as the flatness rate increases 1%, carbon dioxide emissions will decline by 100,000 tons to 300,000 tons annually. If buffering can be performed on a large scale throughout society by reducing the variations, the benefits gained by society as a whole will be tremendous.

Another significant effect will be lower transmission losses. With the local on-demand electric power network, electricity will not have to be transmitted over long distances. It is said that each electric power supply company incurs transmission losses in the 4% to 5% range. If these losses could be completely eliminated, the effects would be tremendous, including a 19.72 million ton reduction in carbon dioxide emissions. Of course, this is the ideal result. Although I do not know what percentage would be ideal, eliminating long-distance electric power transmission would have a massive impact on society (Figure 16).

16. Conclusion

At an MIC study group, the participants made a rough calculation of the effects of the on-demand electric power network (Figure 17). If all homes and offices in Japan introduce the EOD system that I discussed earlier, carbon

Estimate of CO_2 Reduction Effects

Source: Ministry of Internal Affairs and Communications, Study Group on ICT Policies on Global Warming

- Estimate of CO_2 reduction potential under distinctive scenarios in 2030

Examples of CO_2 reduction potential estimates

Subject of Digitization	Prospective Scenarios under Distinctive Scenarios in 2030	CO_2 Reduction Potential
Energy flows	Eco-energy management systems	31.5 m tons/year
	Proactive HEMS (EOD)	8.5 m tons/year
	Proactive BEMS (EOD)	23 m tons/year
Flows other than energy (people, goods, money)	Electronic paper use for newspapers	5 m tons/year
	Reduction in overseas business travel through the use of ultra-realistic conferencing systems	1.7 m tons/year

* Carbon dioxide emissions relating to the operation of ICT devices are expected to be small compared to the reductions in emissions resulting from their use and so they are excluded from this calculation.

Network energy consumption

- Large routers will be replaced by optical fiber routers which use less energy.
- Future traffic will increase explosively resulting in increased electric power consumption by routers and other devices of 130 billion kWh by 2030.
- Creation of total optical network node technologies will reduce energy consumption to one-fiftieth compared to current large routers and to one-half compared to small routers.

As a result, the increase in power consumption from network devices can be kept to 45 billion kWh in 2030.

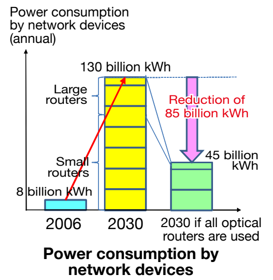


Figure 17 – Expected CO_2 reductions

dioxide emissions would be reduced by 31.5 million tons per year. This is an extremely large contribution to reducing carbon dioxide emissions.

Nonetheless, in such a case, telecommunications network usage would increase, and electric power consumed by network devices would increase from 8 billion kWh in 2006 to 130 billion kWh in 2030. If further advances are made in energy saving by routers, computers, and other devices, this can be reduced by 45 billion kWh. The reduction in carbon dioxide emissions by the introduction of the EOD system is greater than the increase from greater energy consumption by network devices and so the overall effect will be worthwhile.

I would like everyone, not just those of you in attendance here today but also young people as well, to understand that we will build the society of the twenty-first century using ICT and that telecommunications has finally entered the second phase. The real development starts now.

Thank you for your attention.

(From the 40th World Telecommunication and Information Society Day Commemorative Lecture on May 16, 2008)

Author speaking at the 40th World Telecommunication and Information Society Day commemorative lecture